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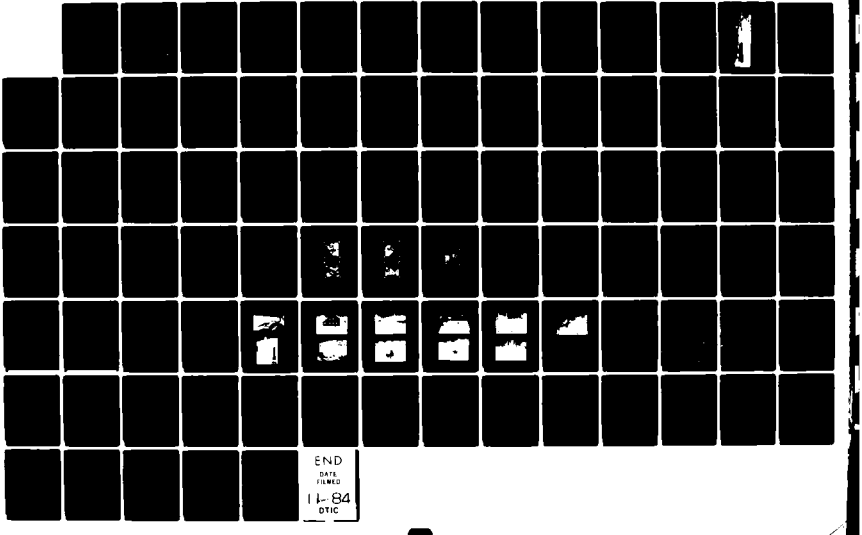

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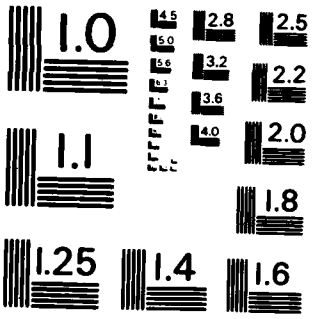

MERRIMACK RIVER BASIN
TOWNSEND, MASSACHUSETTS

TOWNSEND HARBOR DAM
MA 00138

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

JUNE 1979

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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4. TITLE (and Subtitle) Townsend Harbor Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT 6. PERFORMING ORG. REPORT NUMBER
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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Merrimack River Basin
Townsend, Mass.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Townsend Harbor Dam consists of a 100 foot long earth embankment 11 feet high at the right, a 92 foot long stone masonry spillway 8 feet high at the center and 57 foot long stone masonry wall retaining apparent fill at the left side of the dam. The dam is in fair condition. Based on the size, small, and hazard classification, significant, the spillway test flood is the ½ PMF.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED

SEP 17 1979

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

Dear Governor King:

I am forwarding to you a copy of the Townsend Harbor Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, Hollingsworth & Vose Co., Townsend Road, West Groton, Massachusetts 01472.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely yours,

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

MERRIMACK RIVER BASIN
TOWNSEND, MASSACHUSETTS

TOWNSEND HARBOR DAM
MA 00138

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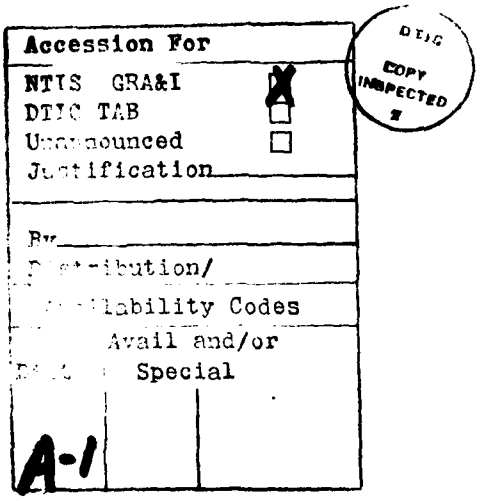
TOWNSEND HARBOR DAM
MA 00138

MERRIMACK RIVER BASIN
TOWNSEND, MASSACHUSETTS



PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

Identification No. : MA 00138
Name of Dam: TOWNSEND HARBOR DAM
Town: TOWNSEND
County and State: MIDDLESEX, MA
Stream: SQUANNACOOK
Date of Inspection: 15 NOVEMBER 1978

BRIEF ASSESSMENT

Townsend Harbor Dam consists of a 100 foot long earth embankment 11 feet high at the right, a 92 foot long stone masonry spillway 8 feet high at the center and 57 foot long stone masonry wall retaining apparent fill at the left side of the dam. The outlet works of the reservoir, a millrace, is to the left of the stone masonry wall. The millrace has an abandoned concrete control structure near its mid-length, a concrete overflow near the three-quarter point and a concrete control structure with stop logs at the discharge end which is approximately 200 feet downstream of the spillway.

The dam is in fair condition. Slight seepage was observed at the right end of the spillway and from under the old grist mill building. Brush, trees and debris are present on the dam and dike embankments and in the downstream channel.

Based on the size, small, and hazard classification, significant, in accordance with the Corps of Engineers Guidelines, the spillway test flood is the 1/4 Probable Maximum Flood (1/4 PMF). The test flood peak outflow was estimated to be 14,610 cfs and would result in overtopping the dam by approximately 7.5 feet; however, under such a flooding condition the dam would be essentially submerged by tailwater. Hydraulic analysis indicates that the spillway will only pass 43 percent of the test flood.

Recommended additional investigations by the Owner include a detailed hydrologic-hydraulic study of spillway capacity, an investigation of the protection of the millrace dike and an investigation of seepage at the grist mill foundation and at the right end of the spillway. Recommended remedial measures include the cutting of brush and trees at the dam, dike and discharge channel, the repair of locally eroded areas and spillway apron and the establishment of formal maintenance program, operational procedures and emergency preparedness plan and warning system. These recommendations and remedial measures as delineated in Section 7 of the report should be undertaken within one year of receipt of the report by the Owner.

CAMP DRESSER & McKEE INC.

Roger H. Wood

Roger H. Wood
Vice President

This Phase I Inspection Report on Townsend Harbor Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgement and practice, and is hereby submitted for approval.

Joseph W. Finegan

JOSEPH W. FINEGAN, JR., MEMBER
Water Control Branch
Engineering Division

Joseph A. McElroy

JOSEPH A. MCELROY, MEMBER
Foundation & Materials Branch
Engineering Division

Carney M. Terzian

CARNEY M. TERZIAN, CHAIRMAN
Chief, Structural Section
Design Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I Investigations are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the test flood is based on the estimated "probable maximum flood" for the region (greatest reasonably possible storm runoff), or a fraction thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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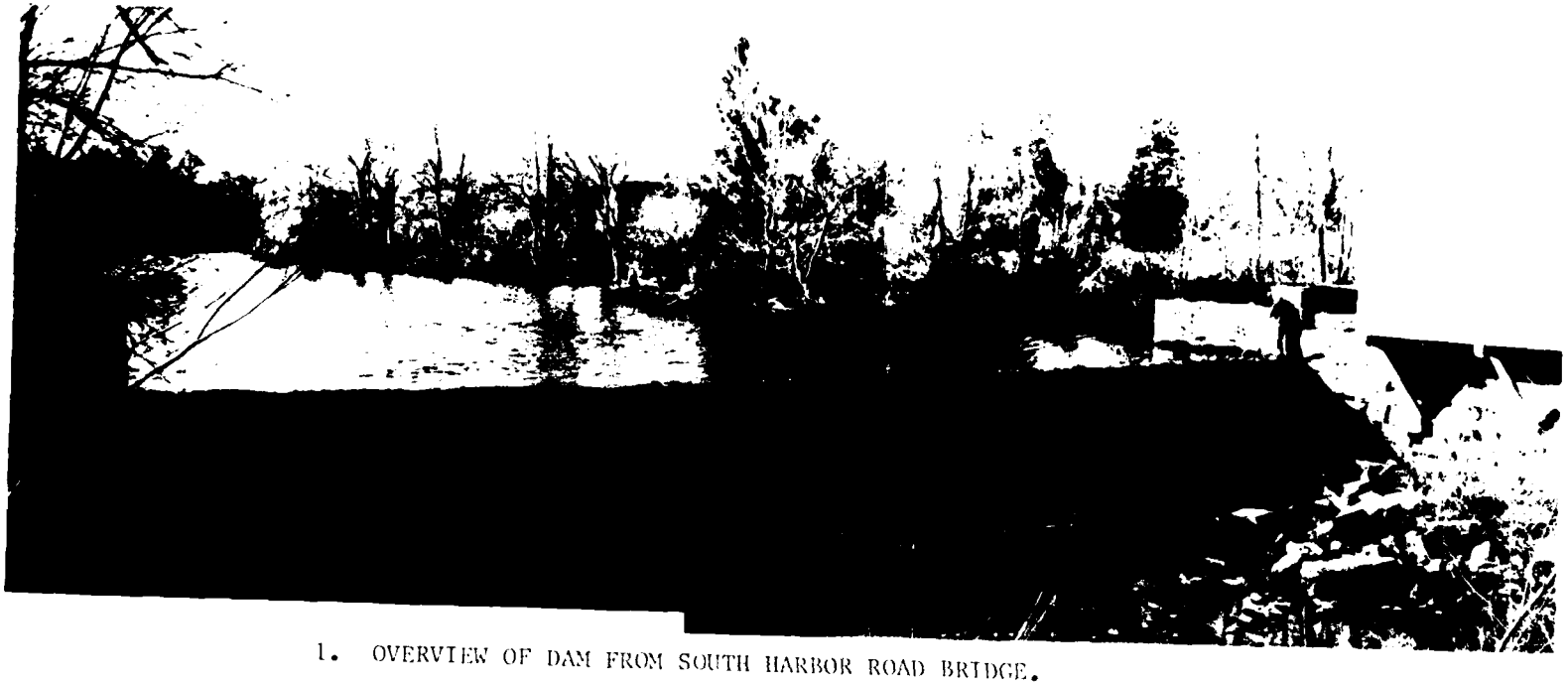
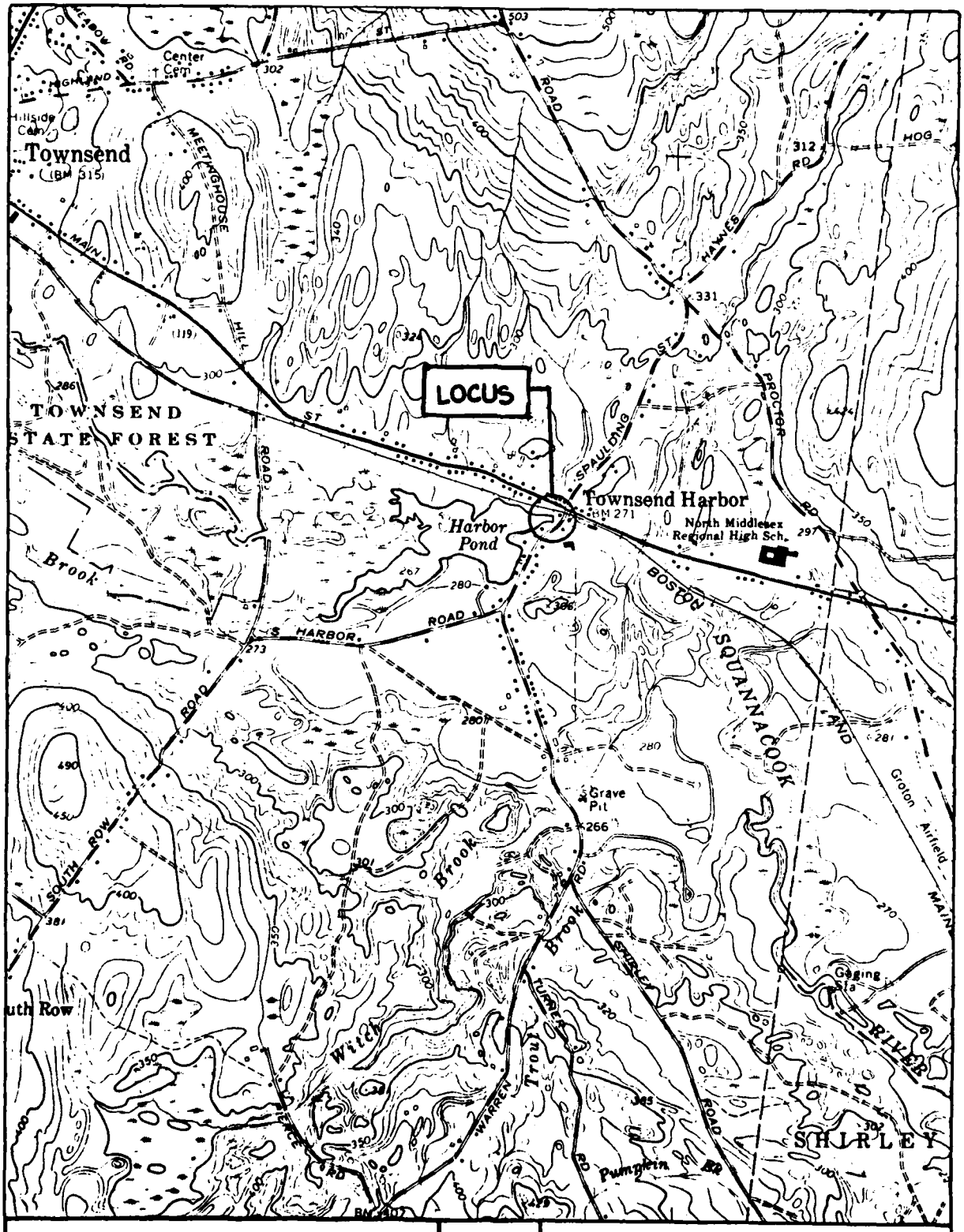
APPENDIXES



1. OVERVIEW OF DAM FROM SOUTH HARBOR ROAD BRIDGE.



DAM TOWNSEND HARBOR DAM

IDENTIFICATION NO. MA 00138

LOCATION MAP
USGS QUADRANGLE
TOWNSEND, MASS. - N.H.

APPROX. SCALE: 1" = 2000'

PHASE 1 INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

TOWNSEND HARBOR DAM
MA 00138

SECTION 1: PROJECT INFORMATION

1.1 General

a. Authority - Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England region.

Camp Dresser & McKee Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued to Camp Dresser & McKee Inc. under letters of 12 July 1978 and 23 October 1978 from Colonel John P. Chandler, Corps of Engineers. Contract No. DACW 33-78-C-0354 has been assigned by the Corps of Engineers for this work. Haley and Aldrich, Inc. has been retained by Camp Dresser & Inc. for soils and geological portions of the work.

b. Purpose - The primary purpose of the investigation is to:

(1) Perform technical inspection and evaluation of non-federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-federal interests.

(2) Encourage and assist the states to initiate quickly effective dam safety programs for non-federal dams.

(3) Update, verify and complete the National Inventory of Dams.

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(3) Update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location - Townsend Harbor Dam is located on the Squannacook River, approximately 95 feet upstream of South Harbor Road and adjacent to Main Street in the Town of Townsend, Massachusetts, as shown on the report's location map. Water impounded by the dam is called Harbor Pond.

b. Description of Dam and Appurtenances - Townsend Harbor Dam consists of a 92.2-ft. long, 8.3-ft. high stone-masonry overflow spillway flanked on the right by a 100 foot long low earth embankment and on the left by an area of apparent fill retained by a 57-ft. long stone-masonry wall.

A 17.6-ft. wide millrace runs parallel to the Squannacook River around the left abutment area past old mill buildings and rejoins the downstream channel over 200 feet below the dam. A 16.3-ft. long railroad bridge forms the entrance to the millrace, which is a stone-masonry-walled channel upstream of South Harbor Road and is a concrete channel downstream. A 3.9-foot-wide, stop-log controlled concrete outlet at the end of the millrace allows the flow to return to the Squannacook River.

Short stone masonry walls extend about 8 feet from the right spillway training wall along the upstream and downstream faces of the right dam embankment. Beyond these walls, extending to a total length of approximately 100 feet from the spillway, there is an irregularly-shaped grass and brush-covered earth embankment. The embankment height varies from a maximum of approximatley 13 ft. at the spillway to a junction with natural ground in a private yard. The embankment crest is about 2.7 feet above the level of the spillway crest.

To the left of the spillway, the apparent filled area is relatively level at 2.8 feet above the spillway crest and is bounded by the left spillway and channel walls to the south, a stone-masonry upstream wall to the west, the millrace to the north, and South Harbor Road to the east. Most of the surface is grass and weeds, but there is one large wood-frame building called "The Cooperage" that projects over the downstream river channel.

Downstream of South Harbor Road the millrace generally parallels the river channel, with its river-side bank about 12 feet above the river channel. An 80-ft. long section of this bank, between an old wood frame grist mill near South Harbor Road and the concrete millrace outlet structure near another mill building, functions as an earth dike. The dike has a crest width that varies from 10 to 20 feet, an upstream concrete wall, and a partial downstream stone-masonry wall. Most of the millrace dike crest has a cover of grass and weeds with some trees and brush, while the gradual slope from the downstream wall to the river channel has more trees and brush.

c. Size Classification - Townsend Harbor Dam has a height of approximately 11 feet and a storage capacity of 273 acre-feet at the top of the dam. According to guidelines established by the Corps of Engineers, the dam is classified in the small category.

d. Hazard Classification - Based on the results of the dam failure analysis included in Section 5 of this report, failure of the dam could jeopardize a few lives due to the presence of a building on the left side of the downstream channel. The dam is, therefore, classified in the significant hazard category.

e. Ownership -The dam and millrace have been owned by Hollingsworth & Vose Company for the past 18 years. The previous owner is reported to be Townsend Harbor Investments Inc., from which Hollingsworth & Vose Co. purchased the property. The address of the present owner is: Hollingsworth & Vose Company, Townsend Road, West Groton, Massachusetts, 01472. Mr. A.E. Irelan at the above address is the owner's representative.

f. Operator - Operation of the dam is the responsibility of Mr. A.E. Irelan of Hollingsworth & Vose Co. His address is Hollingsworth & Vose Co., Townsend Road, West Groton, Massachusetts, 01472 (phone 617/448-3311).

g. Purpose of Dam - A dam was originally constructed at this general area in 1733 as a water supply for a saw mill which eventually became a grist mill. In 1870, the present dam was constructed to provide additional power for the Spaulding Leatherboard Company. The present owner utilizes the dam as a water reservoir to supplement extreme dry-weather river flow.

h. Design and Construction History - There are no records of the design or construction of this dam. A newspaper account and plaque at the site indicate that a dam was originally built in 1733 in this area. The present dam was constructed in 1870 and rebuilt or repaired after being damaged in 1936 and 1938.

i. Normal Operational Procedures - There is no formally-established routine for operation of the dam. Mr. Irelan stated that Harbor Pond is maintained at approximate spillway crest elevation year-round with stop logs located at the millrace outlet. During very dry periods, the operator increases the flow through the millrace by removing the stop logs.

1.3 Pertinent Data - Elevations used in this report are on National Geodetic Vertical Datum (NGVD), formerly referred to as Mean Sea Level Datum (MSL). The elevations previously established at the dam site and shown on the plan included in Appendix B are on NGVD and agree with those shown on the USGS Quadrangle, Townsend, Mass., 1965.

a. Drainage Area - The drainage area tributary to the dam site is 58.3 square miles and is characterized by moderately-forested, lightly-developed rolling terrain. In the vicinity of Harbor Pond, the terrain is flat and swampy. Harbor Pond accounts for approximately 0.1 percent of the total drainage area.

b. Discharge at Dam Site - There are no records of discharges at the dam site, but Squannacook River discharges are recorded at USGS Gage Number 01096000 located approximately 2 miles downstream of the dam site.

(1) Outlet works size----------3.9 ft. wide by 2.8 ft. high box outlet

(2) Maximum known flood at damsite----------Unknown

(3) Ungated spillway capacity at top of dam
1,430 cfs @ 270.0 elev.

(4) Ungated spillway capacity at test flood elevation
6,320 cfs @ 277.5 elev.

(5) Gated spillway capacity at normal pool elevation----------N/A

(6) Gated spillway capacity at test flood elevation----------N/A

(7) Total spillway capacity at test flood elevation
6,320 cfs @ 277.5 elev.

(8) Total project discharge at test flood elevation
14,610 cfs @ 277.5 elev.

c. Elevation (NGVD)

(1) Streambed at centerline of dam----------259.0 (Est)

(2) Test flood tailwater----------275.0

(3) Upstream portal invert diversion tunnel----------N/A

(4) Normal pool----------267.3

(5) Full flood control pool----------N/A

(6) Spillway crest----------267.3

(7) Design surcharge (Original Design)----------Unknown

(8) Top of dam----------Varies, low point at 270.0

(9) Test flood design surcharge----------277.5

d. Reservoir

(1) Length of test flood pool----------8,400 ft.

(2) Length of normal pool----------3,500 ft.

(3) Length of flood control pool----------N/A

e. Storage (acre-feet)

(1) Normal pool----------116.0

(2) Flood control pool----------N/A

(3) Spillway crest pool----------116.0

(4) Top of dam----------273.0

(5) Test flood pool----------2,646

f. Reservoir Surface (acres)

(1) Normal pool----------43.5

(2) Flood-control pool----------N/A

(3) Spillway crest----------43.5

(4) Test flood pool----------374.4

(5) Top of dam----------197.4

g. Embankments

		Right Embankment	Millrace Dike
(1)	Type	Earth fill	Earth fill with concrete upstream face and partial stone-masonry downstream face
(2)	Length	Approx. 100 ft.	Approx. 80 ft.
(3)	Height	Approx. 11 ft. max	Approx. 12 ft.
(4)	Top width and elevation	20 ft. max at elev. 270	10 to 20 ft. at elev. 270.2
(5)	Side slopes	Irregular U/S & D/S	Vertical walls with irregular base slopes which are flatter than 3H to 1V slope below downstream wall.

(6)	Zoning	Unknown	Unknown
(7)	Impervious core	Unknown	Unknown
(8)	Cutoff	Unknown	Unknown
(9)	Grout curtain	Probably none	Probably none

h. Diversion and Regulating Tunnel----------None

i. Spillway

(1) Type----------Stone masonry

(2) Length of weir----------92.2 ft.

(3) Crest elevation----------267.3 MSL

(4) Gates----------None

(5) U/S Channel----------None

(6) D/S Channel---------- 85-ft. wide river at 0.0015 slope

j. Regulating Outlets - Flow at the dam can be regulated by insertion or removal of stop logs at the control structure at the downstream end of the millrace. The discharge opening is 3.9 feet wide and, without stop logs, is 6.1 feet high, with an estimated invert elevation of 263.1. Normally, there are 3.3 feet of stop logs at the outlet, setting the normal weir crest at elevation 266.4. There is an uncontrolled overflow spillway from the millrace to the Squannacook River located approximately 23 feet upstream from the downstream millrace control structure. The overflow spillway crest is at elevation 268.3 and is approximately 18 feet long.

SECTION 2. ENGINEERING DATA

2.1 Design Records - No design records were located for the Townsend Harbor Dam.

2.2 Construction Records - No records of the original construction were located.

2.3 Operation Records - No operational records were located for the dam.

2.4 Evaluation

a. Availability - No records for the dam other than prior inspection reports were located.

b. Validity - There are no known design, construction or operating records.

c. Adequacy - The absence of known records requires that the evaluation of the dam during this investigation be based on the visual examination described in the following section.

SECTION 3: VISUAL INSPECTION

3.1 Findings

a. General - The Phase I visual examination of Townsend Harbor Dam was conducted on 15 November 1978. In general, the structures were observed to be in fair condition. It should be noted that the only pond drain for this structure is the millrace channel.

Visual inspection checklists for the dam are included in Appendix A, and selected photographs are given in Appendix C.

b. Dam and Spillway - The spillway, and the earth embankments on each side of it, show no visual evidence of major lateral movement or settlement. The open-joint stone-masonry spillway and the left wall between the dam and South Harbor Road appear to be stable. The walls to the right of the spillway are in fair condition. Minor seepage is present at the juncture of the spillway and downstream wall parallel to the crest of the embankment, while portions of the flared downstream wall are displaced. The earth embankment located to the right of the spillway is generally in fair condition, with no visual evidence of major erosion or seepage.

The following specific items were noted:

1. Quarry stone debris just downstream of the spillway on the left side appears to be apron stone which may have been broken or dislodged from the apron and moved downstream. It appears that some of the pieces from the apron have been used as protection for the right wing wall of the South Harbor Road bridge.

2. Much of the right embankment surface is mowed lawn, but there is considerable growth of brush and trees on the downstream face and near the spillway. Leaves and branches have been dumped on part of the downstream face.

3. There is local slight erosion of the right embankment at the end of the short downstream masonry wall.

4. There is slight water flow through joints, as shown in Photo 12, in the right downstream masonry wall which is parallel to the embankment crest.

5. The crest of the right dam embankment is irregular, and is slightly low immediately behind the masonry wall at the spillway.

6. There is some brush growth in the channel downstream of the spillway.

7. The right downstream flared stone masonry wall has areas of displaced stones.

c. Appurtenant Structures - The stone-masonry wall just upstream of the millrace entrance at the railroad bridge is in good condition. Heavy brush, however, was observed along both sides. The millrace dike is in poor condition, due to extensive erosion and other deficiencies. The upstream millrace control structure was in good condition, but the stop-log guides were in poor condition. No stop logs were observed. The millrace downstream of South Harbor Road and the downstream control structure are of concrete and are in good condition. Submerged stop logs were observed at this structure during the site visit. The overflow spillway on the right side of the millrace is in good condition with minor vegetation at the crest. On the left side of the channel just upstream of the downstream control structure there is evidence of a former continuation of the millrace through the buildings located downstream along the left river bank.

The following additional specific items were noted:

1. The millrace dike has major erosion loss near the corner of the old grist mill and behind about half the length of the upstream stone-masonry wall. The erosion appears to have been at least partly the result of overtopping.

2. Part of the millrace dike crest has brush and tree growth, as shown in Photos 7, 8, and 9, while the eroded portions are bare of any vegetation.

3. There is a large, partly stone-filled, depression immediately below the millrace dike overflow spillway, apparently the result of scour from past spillway flows.

4. Slight seepage flow is emerging from under the grist mill building next to the downstream river channel. This flow may originate at the other end of the building basement, where there would have been a gated waterway connection to the millrace.

d. Reservoir Area - The area around Harbor Pond is moderately developed. There appear to be no structures below elevation 270, but there are approximately 35 structures below elevation 280. The side slopes of the pond are generally flat and swampy. There is no apparent potential for significant landslides into the pond which could create waves that might overtop the dam. No conditions were noted which could result in a sudden increase in sediment load in the pond.

The Squannacook River enters Harbor Pond approximately 3,500 feet upstream (west) of the dam. The channel meanders slightly, and its slope varies from 0.05 percent near the pond to 0.13 percent near the center of the Town of Townsend.

e. Downstream Channel - The Squannacook River downstream of the dam is approximately 85 to 100 feet wide, appears to be unobstructed, and has very little development along its banks. The slope is approximately 0.13 percent. There appear to be two other dams on the Squannacook River before its confluence with the Nashua River, approximately 7 miles downstream.

3.2 Evaluation

The masonry spillway, side embankments and appurtenances appear to be performing satisfactorily at the present time. The seepage observed at the right masonry wing wall adjacent to the spillway, however, could cause future problems if allowed to continue. Furthermore, the limited millrace dike freeboard and partially-unprotected dike embankment appear to provide potential for failure under conditions of water levels which overtop the embankments.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures - There is no formal procedure for operation of the dam. On an informal basis, the Owner attempts to control flow over the spillway by removing stop logs at the downstream end of the millrace. During extreme low flow, the Owner removes additional stop logs, releasing water impounded by the dam and spillway for his use as process water at a downstream mill.

4.2 Maintenance of Dam - There is no established formal maintenance program for this dam. The operator indicated that the dam is inspected twice a year and maintenance is performed on a demand basis.

4.3 Maintenance of Operating Facilities - There is no formal procedure for maintenance of operating facilities (millrace control structures).

4.4 Description of Any Warning System in Effect - There is no established warning system or emergency preparedness plan in effect for the dam. The operator indicated that the dam is observed during periods of high water.

4.5 Evaluation - Formal operational procedures should be established for high-flow conditions at the dam. Formal maintenance programs, warning systems and emergency preparedness plans should also be established. Periodic observation should be made, and the tree and brush growth at the embankments should be brought under control. Maintenance of the dam should be performed at regular intervals.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. General - Harbor Pond is formed by the Townsend Harbor Dam on the Squannacook River, which is a tributary of the Nashua River approximately 7 miles downstream of the dam. The surface area of the pond is approximately 44 acres at spillway crest and approximately 197 acres at the top of the dam. The dam impounds approximately 116 acre-feet of water at spillway crest and approximately 273 acre-feet at the top of the dam.

The stone masonry spillway, at crest elevation 267.3, is 92.2 feet long. The low point of the right embankment of the dam is at elevation 270. The left embankment, at elevation 270.1, extends 57 feet from the dam to the railroad bridge at the entrance to the millrace. The millrace entrance consists of a box culvert 16.3 feet wide, 6.6 feet high and 11.5 feet long, with an invert elevation of 263.1.

There are several means of discharge from the millrace, depending on the water surface elevation. The invert of the normal discharge opening, 3.9 feet wide and 6.1 feet high, is 263.1. However, the 3.3 feet of stop logs normally maintained in this opening sets the normal operating weir at 266.4. The overflow spillway upstream of the normal discharge opening is at elevation 268.1 and is 18 feet long. The walls on both sides of the overflow spillway form an additional 44.4 feet of weir at elevation 269.2. The top of the wall above the normal discharge opening forms an additional 15-foot weir at elevation 270.2. The side wall of the remainder of the millrace, upstream of South Harbor Road, is at elevation 272.1.

b. Design Data - No hydraulic/hydrologic design data are available for the dam.

c. Experience Data - A newspaper report indicates that the dam and South Harbor Road bridge were "washed out" during the 1936 flood and were rebuilt in 1937. The report further states that the dam was repaired after the 1938 hurricane.

USGS Gaging Station 01096000 has recorded Squannacook River flows approximately 2 miles downstream of the dam since October 1949. The drainage area tributary to the gage is 62.8 square miles, which is only 4.6 square miles more than that tributary to the dam site. Flows recorded at the gage, therefore, should be only slightly greater than flows at the dam site. Some of the larger flows recorded at the gage have been: 4,010 cfs (October 16, 1955); 2,760 cfs (March 14, 1977); 2,340 cfs (April 2, 1962); and 2,260 cfs (March 19, 1968).

d. Visual Observations - The pond level was at spillway crest at the time of inspection. The millrace and downstream channel appeared to be in good hydraulic condition, with the exception of some vegetation in the river bed.

e. Test Flood Analysis - Based on the Corps of Engineers guidelines, the recommended test flood for the size (small) and hazard potential (significant) is between the 100-year flood and one-half of the Probable Maximum Flood (PMF). The 1/4 PMF was adopted as the test flood and was determined using Corps of Engineers guidelines for "Estimating Maximum Probable Discharge" in Phase I Dam Safety Investigations. The watershed terrain is characterized as rolling, and a PMF inflow rate of 1,100 cubic feet per second (cfs) per square mile was adopted for the 58.3-square-mile drainage area. The resulting test-flood inflow is 16,000 cfs.

Initial surcharge-storage routing of the test-flood inflow through Harbor Pond resulted in a peak test-flood outflow of 14,840 cfs at a surcharge pond stage of 275.9 feet above NGVD. Stage discharge relationships, presented in Appendix D, include the discharge capacity of the millrace. Due to the indicated tailwater elevation of 275.7, further analysis was performed to account for submergence. The subsequent surcharge-storage routing resulted in a peak test-flood outflow of 14,610 cfs at a surcharge pond stage of 277.5 feet above NGVD. At this stage, which is 10.2 feet above the spillway crest, the dam will be overtopped by 7.5 feet. The spillway capacity at test flood is approximately 6,320 cfs, and the tailwater elevation is approximately 275.0.

f. Dam Failure Analysis - Dam failure analysis was performed in order to assess the downstream hazards in the event of dam failure. A peak failure outflow of approximately 3,130 cfs was estimated based on a breach width of approximately 37 feet and with the pond at the top of the dam (270.0 feet above NGVD), which is 2.7 feet above the spillway crest. Water flowing 2.7 feet deep over the spillway is equivalent to a flow of 1,430 cfs. Such a wet-weather flow would produce flooding conditions downstream prior to dam failure. While this flooding would not be expected to endanger lives downstream, it is estimated that the sudden release of an additional 1,700 cfs in a dam failure would severely damage the building on the left bank just downstream of the South Harbor Road bridge with potential loss of a few lives. Approximately 1.6 miles downstream, a building on Trout Brook in the right flood plain of the Squannacook River would also be flooded by the dam-failure flow. Accordingly, Townsend Harbor Dam is classified as having a "significant" hazard potential.

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observation - There was no visible evidence of spillway or dam embankment instability during the site examination of 15 November 1978. The observed locations of slight seepage at the right end of the spillway and under the old grist mill building showed no evidence of soil movement, and are not considered to pose an immediate hazard to the stability of the downstream faces of the embankments.

b. Design and Construction - There are neither design drawings nor construction data which would show the embankment cross sections or the physical properties of the materials in the embankments. Thus, theoretical analyses of the structural stability of the dam embankments are not possible.

The embankments have had a long period of service, and, in the absence of seepage or erosion problems, would be expected to be adequately stable under static loading conditions.

c. Operating Records - No operating records, other than state and county inspection reports, were located.

d. Post-Construction Changes - The dam was constructed in 1870 (the date inscribed on the face of the spillway) to provide additional power for the Spaulding Leatherboard Company. The presence of a concrete millrace, concrete control structures and grouted stone-masonry walls upstream of the spillway further indicate that post-construction changes have been made to the dam.

e. Seismic Stability - The dam is located in seismic zone No. 2 and, in accordance with recommended Phase I Guidelines, does not warrant seismic analysis.

SECTION 7: ASSESSMENTS, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition - The visual examination of the Townsend Harbor Dam and dike embankments did not reveal any evidence of failure or conditions which would warrant urgent remedial treatment. However, because of the need for maintenance and additional investigations that are outlined hereinafter and the limited capacity of the spillway, the project is considered to be in only fair condition.

b. Adequacy of Information - All of the information for the Phase I Investigation had to be obtained from visual examination and limited measurements at the site. This information has been sufficient for the purpose of this investigation, but it does not permit detailed evaluation of stability or seepage.

c. Urgency - The recommended additional investigations and remedial measures outlined in Sections 7.2 and 7.3, respectively, should be undertaken within one year of receipt of the report by the Owner.

d. Need for Additional Investigations - Additional investigations should be performed by the Owner as outlined in the following section.

7.2 Recommendations

It is recommended that the Owner engage a registered professional engineer to perform the following additional investigations:

1. A detailed hydrologic-hydraulic investigation to determine the adequacy of the spillway and any necessary modifications to the facility to provide adequate capacity, taking into account the sumbergence of the dam.

2. An investigation of the millrace geometry, controls and operation to determine a practicable means of protection against overtopping and subsequent erosion damage to the millrace dike.

3. An investigation of the seepage that is emerging from under the old grist mill building and at the masonry wall to the right of the spillway, to determine what corrective or control measures may be necessary.

7.3 Remedial Measures

a. Operation and Maintenance Procedures - It is recommended that the following remedial work be undertaken by the Owner, in addition to the investigations outlined in Section 7.2, to correct deficiencies noted during the visual examination:

(1) Clear brush, trees and debris from the dam and dike embankments including stump removal and backfilling, and cut grass

and weeds on the embankments at least once a year. Clearing of the gradual slope below the millrace dike downstream wall is not necessary beyond 10 ft. from the wall.

(2) Restore displaced apron stones at the downstream face of the spillway.

(3) Fill area of local erosion in the right embankment at the end of the short downstream masonry wall and bring crest of embankment behind the wall to grade.

(4) Reset displaced stones in right downstream flared stone masonry wall.

(5) Restore low and eroded areas in the millrace dike embankment and re-establish vegetative cover. Work on the millrace dike would be subject to the results of the millrace investigation under Section 7.2.

(6) Clear brush from channel immediately downstream of spillway.

(7) Place additional stone protection or dumped riprap in depression at discharge end of millrace overflow spillway.

(8) Establish a formal maintenance program, operational procedures and emergency preparedness plan and warning system.

The Owner should continue his program of technical inspections. These inspections should be made at least at yearly intervals.

7.4 Alternatives - There are no practical alternatives recommended.

APPENDIX A

INSPECTION TEAM ORGANIZATION AND CHECK LIST

VISUAL INSPECTION PARTY ORGANIZATION

NATIONAL DAM INSPECTION PROGRAM

DAM: Townsend Harbor

DATE: 15 November, 1978

TIME: 3:30 PM

WEATHER: Clear and cool-- 40 to 45 F.

WATER SURFACE ELEVATION UPSTREAM: 267.3 (at spillway crest)

STREAM FLOW: $(3.33)(3.9')(0.75')^{3/2} = 8.4$ cfs

INSPECTION PARTY:

1. Robert P. Howard - Structural & Operation
2. Charles E. Fuller - Hydraulics & Hydrology
3. Joseph E. Downing - Ass't. Hydraulics & Hydrology
4. A. Ulvi Gulbey - Ass't. Hydraulics & Hydrology
5. Peter L. LeCount (H & A) - Soils
6. _____

PRESENT DURING INSPECTION:

1. A. E. Irelan - Project Engineer, Hollingsworth & Vose Co.
2. _____
3. _____
4. _____

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Townsend Harbor DATE: 11/15/78

EMBANKMENT: (Rt. of Spillway)

CHECK LIST	CONDITION
1. Upstream Slope	1.
a. Vegetation	a. Grass (lawn)
b. Sloughing or Erosion	b. None evident
c. Rock Slope Protection - Riprap Failures	c. None
d. Animal Burrows	d. None observed
2. Crest	2.
a. Vegetation	a. Grass, scattered brush, tree, two stumps.
b. Sloughing or Erosion	b. Grass intact, but irregular shape
c. Surface cracks	c. None evident
d. Movement or Settlement	d. Not evident-irregular shape
3. Downstream Slope	3.
a. Vegetation	a. Mostly brush & trees, some dumped leaves, branches, etc.
b. Sloughing or Erosion	b. Irregular shape, local slight eros. from runoff at end of masonry wingwall.
c. Surface cracks	c. None evident
d. Animal Burrows	d. None evident
e. Movement or Cracking near toe	e. None evident
f. Unusual Embankment or Downstream Seepage	f. Slight flow thru masonry wall joints close to spillway.
g. Piping or Boils	g. None evident
h. Foundation Drainage Features	h. None evident
i. Toe Drains	i. None
4. General	4.
a. Lateral Movement	a., b., c. Irregular shape w/o defined alignment or indication of movement.
b. Vertical Alignment	
c. Horizontal Alignment	
d. Condition at Abutments and at Structures	d. Embank. sl. low immed. behind masonry wall, but no indication of recent movement.
e. Indications of Movement of Structural Items	e. None evident
f. Trespassing	f. None evident
g. Instrumentation Systems	g. None

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Townsend Harbor DATE: 11/15/78

EMBANKMENT: Dike between Millrace and Spillway

CHECK LIST	CONDITION
1. Upstream Slope a. Vegetation b. Sloughing or Erosion c. Rock Slope Protection - Riprap Failures d. Animal Burrows	1. a., b., c., d. N.A.-Concrete canal wall
2. Crest a. Vegetation b. Sloughing or Erosion c. Surface cracks d. Movement or Settlement	2. a. Grass & weeds, few trees. b. Erosion behind downstream end of canal wall-apparently has been overtopped. d. Only in concrete canal overflow spillway slab.
3. Downstream Slope a. Vegetation b. Sloughing or Erosion c. Surface cracks d. Animal Burrows e. Movement or Cracking near toe f. Unusual Embankment or Downstream Seepage g. Piping or Boils h. Foundation Drainage Feature i. Toe Drains	3. a. Some grass, weeds, brush & trees - mostly stone masonry wall or bare earth. b. Erosion due to surface runoff at corner of bldg., possibly due to overtopping. c. Not evident d. None observed e. None observed f. Ponded seepage in rear of old [illegible] formerly fed by canal. g. None observed h. None observed i. None
4. General a. Lateral Movement b. Vertical Alignment c. Horizontal Alignment d. Condition at Abutments and at Structures e. Indications of Movement of Structural Items f. Trespassing g. Instrumentation Systems	4. a. Not evident b., c. Irregular shape d. Local erosion from overtopping. e. Slight settlement toward end of overflow spillway slab. f. Scattered trash & cans g. None

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Townsend Harbor DATE: 11/15/78

EMBANKMENT: Dike between Millrace and Spillway

CHECK LIST	CONDITION
1. Upstream Slope a. Vegetation b. Sloughing or Erosion c. Rock Slope Protection - Riprap Failures d. Animal Burrows	1. a., b., c., d. N.A.-Concrete canal wall
2. Crest a. Vegetation b. Sloughing or Erosion c. Surface cracks d. Movement or Settlement	2. a. Grass & weeds, few trees. b. Erosion behind downstream end of canal wall-apparently has been overtopped. d. Only in concrete canal overflow spillway slab.
3. Downstream Slope a. Vegetation b. Sloughing or Erosion c. Surface cracks d. Animal Burrows e. Movement or Cracking near toe f. Unusual Embankment or Downstream Seepage g. Piping or Boils h. Foundation Drainage Feature i. Toe Drains	3. a. Some grass, weeds, brush & trees - mostly stone masonry wall or bare earth. b. Erosion due to surface runoff at corner of bldg., possibly due to overtopping. c. Not evident d. None observed e. None observed f. Ponded seepage in rear of old [illegible] formerly fed by canal. g. None observed h. None observed i. None
4. General a. Lateral Movement b. Vertical Alignment c. Horizontal Alignment d. Condition at Abutments and at Structures e. Indications of Movement of Structural Items f. Trespassing g. Instrumentation Systems	4. a. Not evident b., c. Irregular shape d. Local erosion from overtopping. e. Slight settlement toward end of overflow spillway slab. f. Scattered trash & cans g. None

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: TOWNSEND HARBOR DATE: 15 NOVEMBER 1978

SPILLWAY: _____

CHECK LIST	CONDITION
1. Approach Channel a. General Condition b. Obstructions c. Log Boom etc.	1. a. Good. b. None. c. None.
2. Weir a. Flashboards b. Weir Elev. Control (Gate) c. Vegetation d. Seepage or Efflorescence e. Rust or Stains f. Cracks g. Condition of Joints h. Spalls, Voids or Erosion i. Visible Reinforcement j. General Struct. Condition	2. a. None. b. N/A see Outlet Works. c. Minor growth in joints of cut quarry stone face. d. None observed. e. None observed. f. None observed. g. Wall is ungrouted cut quarry stone, one stone has an 1870 date inscribed. h. N/A. i. N/A. j. Good.
3. Discharge Channel a. Apron b. Stilling Basin c. Channel Floor d. Vegetation e. Seepage f. Obstructions g. General Stuct. Condition	3. a. Two courses of cut quarry stone slabs near face of dam stepping down to one course. These quarry stones appear to have been broken and washed downstream. Some pieces have been used as protection of bridge wing wall. b. N/A. c. Earth. d. Heavy brush growth in channel downstream. e. None observed. f. Quarry stone debris left side appears to be apron stone. g. Good.
4. Walls a. Wall Location Lt. & Rt. (1) Vegetation (2) Seepage or Efflorescence (3) Rust or Stains (4) Cracks (5) Condition of Joints (6) Spalls, Voids or Erosion (7) Visible Reinforcement (8) General Struct.Condition	4. a. (1) None observed. (2) Seepage at base of rt. wall that runs parallel with spillway. (3) None observed. (4) None observed. (5) Grouted cut stone block walls upstream of spillway need re-grouting. Downstream walls are ungrouted cut stone block walls. Conditions of joints are good. (6) None observed.

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: TOWNSEND HARBOR DATE: 15 NOVEMBER 1978

SPILLWAY: (cont'd)

CHECK LIST	CONDITION
	4. (7) N/A. (8) Good except rt. wall downstream of spillway is in poor condition.

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: TOWNSEND HARBOR DATE: 15 NOVEMBER 1978
OUTLET WORKS: MILLRACE

CHECK LIST	CONDITION
1. Inlet a. Obstructions b. Channel c. Structure d. Screens e. Stop Logs f. Gates	1. a. None. b. Submerged. c. Railroad bridge abutments show repairs and modifications. Upstream edge of concrete seat on rt. abutment is badly cracked and separating from abutment. d. None. e. None. f. None.
2. Control Facility a. Structure b. Screens c. Stop Logs d. Gates e. Conduit f. Seepage or Leaks	2. a. Upstream Control Facility a. Good condition. b. None. c. Submerged, guides in poor condition. d. None. e. None. f. N/A.
3. Outlet a. Structure b. Erosion or Cavitation c. Obstructions d. Seepage or Leaks	2. b. Downstream Control Facility a. Good condition, some minor erosion of concrete. b. None. c. Submerged. d. None. e. None. f. None observed.
4. Mechanical and Electrical a. Crane Hoist b. Hydraulic System c. Service Power d. Emergency Power e. Lighting f. Lightning Protection	3. a. Good condition. b. None observed. c. None observed. d. None observed.
5. Others	4. N/A. 5. Spillway on right side of channel in good condition with some minor growth. Spillway on left side of channel has been abandoned.

APPENDIX B

LIST OF AVAILABLE DOCUMENTS AND PRIOR INSPECTION REPORTS

LIST OF AVAILABLE DOCUMENTS

Survey plan No. 3048, at 1" = 40 ft. scale, prepared for Hollingsworth & Vose Company by Charles A. Perkins Co., Engineers & Surveyors, Littleton, Mass., November 1961.

TOWN Townsend, Mass DAM NO. E-1

LOCATION Int. Main St. & Harbor Rd. STREAM Squannacook River

MIDDLESEX COUNTY ENGINEERING DEPARTMENT
CAMBRIDGE, MASSACHUSETTS

DAM INSPECTION REPORT

Owned by Mr. Aksila Place Townsend Harbor, Mass. Use None at Present

Inspected by Richard D. Howard Date 7-18-61

Type of Dam Stone Overflow Condition Good

SPILLWAY Length 92' Ht. to Top Emb. Section 4.5'

Flashboards in Place None Ht. of Recent Repairs None

Condition Excellent

Repairs Needed None

EMBANKMENT Length None Height Type

Recent Repairs

Condition

Repairs Needed

GATES Number 2 (In Canal) Size 5'-6" x 5'-5" Types Stop log

Recent Repairs None

Condition Not operating -- remain open

Repairs Needed None

LEAKS Detailed Description and Location on Back of Sheet

How Serious

DATE: 7-18-61 Richard D Howard
Signature Inspecting Engineer

Rec. Action - See Back of Sheet Engineer, Metcalf & Eddy
Title

Special Remarks and Characteristics on Back of Sheet

LEAKS: None

RECOMMENDED ACTION: None

SPECIAL REMARKS: None

J-Mcc Dams
GET/cv
8/31/61

REPORT
UPON
TOWNSEND HARBOR DAM
TOWNSEND HARBOR, MASSACHUSETTS

General

The Townsend Harbor Dam across the Squannacook River is located at Townsend Harbor about 200 feet southwest of the intersection of Main Street and Harbor Road. The dam is an overflow type structure of stone masonry construction. The dam is not used for any purpose. A canal, about 100 feet from the left abutment of the dam, runs parallel to the river. The entrance to the canal is just upstream from the left dam abutment. A Boston and Maine Railroad track runs parallel to the canal about 70 feet from the left end of the dam.

The spillway is about 6.2 feet high and 92 feet long. The depth of the spillway at the crest is 4.5 feet. Due to the elevation of the top of the left upstream abutment wall being 1.7 feet lower, the effective depth at the spillway crest is 2.8 feet. The structure is a triangular crested type with the upstream face sloping downward and upstream at the rate of 0.09 feet to the foot. The downstream face is vertical.

The abutment walls are of stone masonry, 2 feet thick. The left abutment wall forms a right angle about 20 feet upstream from the dam, runs parallel to the intake of the canal and connects to an abutment of a railroad bridge over the canal intake.

The right abutment is U shaped. Training walls lead downstream from the abutments.

A frame building, named "The Cooperage" and used as a gift shop, is located about 12 feet downstream from the dam on the left bank. The structure extends over the stream from the top of the training wall for a distance of about 9 feet.

Conclusions and Recommendations.

1. The present spillway capacity of the dam is about one-seventh the Rare Flood Flow as determined by the Kinnison-Colby Formula.

2. The dam may be protected by the following method:

   a. Raise the tops of all abutment walls at and upstream from the dam to El. 272.1.

   b. Extend the right abutment to meet the ground at El. 272.1.

   c. Protect the abutments with stone riprap.

Spillway Capacity and Flood Flows

The capacity of the 92 ft. long spillway is estimated to be 1290 c.f.s. without provision for freeboard. The canal can divert a flow of about 130 c.f.s. making a total of 1420 c.f.s. The tributary drainage area is 60.6 square miles. The maximum flood flow as estimated from the Kinnison-Colby Formula (Rare Floods) is about 9000 c.f.s. This rate of flow is about 7 times the discharge capacity of the spillway and about 6-1/2 times the combined discharge capacities of the spillway and canal.

It is possible that during a flood, the waterways between the trestlebents of the railroad bridge over the entrance to the canal would become blocked with debris so that diversion of water by the canal would become negligible.

In order for the spillway to discharge the entire estimated rare flood flow of 9000 c.f.s., the head on the spillway crest would have to be increased to 10.4 feet. Due to the location and grade of the railroad trestle bridge there appears to be no practical way to accomplish this by raising the height of the walls on the left abutment. The right abutment wall would have to be increased 5.9 feet in height and extended to Harbor Road.

If the tops of all the abutment walls were raised to El. 272.1, or the elevation of the top of the railroad bridge abutments, the capacity of the spillway could be increased to about 2900 c.f.s. or about 2-1/4 times the present capacity. The right abutment walls could either be extended into the hillside slope or a short earth embankment could be constructed in place of the wall extension.

Stability and Repairs

The stability of the structure is adequate. The condition of the dam is good.

In order to obtain a substantial increase in spillway capacity, the tops of all abutment walls upstream from the dam should be raised to El. 272.1. These walls would be raised 0.3 feet except the upstream left abutment wall which would be raised 2.0 feet. On the right abutment the raised wall should

either be extended a few feet into the hillside slope or connected to the slope with an earth dike. The abutments on both sides of the dam should be protected with stone riprap. On the left abutment this stone protection may be in the form of stone paving on the ground behind the walls for a distance of at least 10 feet from the backface of the wall. On the right abutment the junction of the ground with the end of the extended wall together with the ground on the downstream face of the wall should be protected with dumped stone riprap. If a connecting earth dike is used, it should be completely covered with stone.

By: Gordon E. Thomas
Gordon E. Thomas
Project Engineer

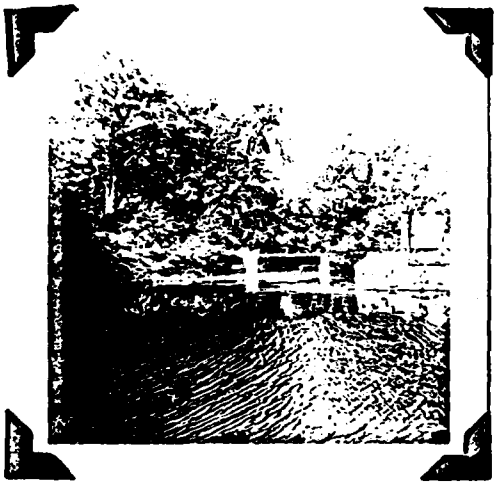
TOWNSEND HARBOR DAM E-1 TOWNSEND HARBOR, MASS.

PICTURES TAKEN JULY 18, 1961

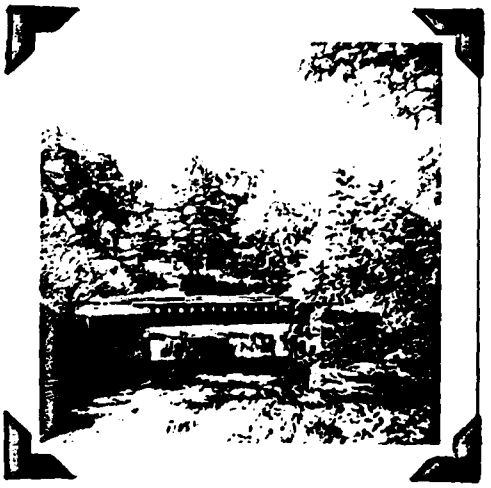
STOPLOG GATES IN BY-PASS CHANNEL

HIGHWAY BRIDGE DOWNSTREAM

TOWNSEND HARBOR DAM E-1 (CONTINUED)



RAILROAD BRIDGE AND NORTH UPSTREAM ABUTMENT



RAILROAD BRIDGE AND POND BEYOND

TOWNSEND HARBOR DAM E-1 (CONTINUED)

SPILLWAY

OK FILE #21

INSPECTION REPORT - DAMS AND RESERVOIRS

(1.) Location: ~~City~~/Town TOWNSEND Dam No. 4-9-299-1

Name of Dam TOWNSEND HARBOR DAM Inspected by A.Z. PIZANO F.H. PARE

Date of Inspection 9-6-'73

(2) Owners: per: Assessors ✓ Prov. Inspection _____

Reg. of Deeds _____ Pers. Contact _____

	Name	St. & No.	~~City~~/Town	State	Tel. No.
1.	HOLLINGSWORTH & VOSE CO.	TOWNSEND ST.	W. GROTON	MASS.	01450 448-3311
2.					
3.					

(3) Caretaker: (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Name	St. & No.	City/Town	State	Tel. No.
SAME				

(4) No. of Pictures taken 2

(5) Degree of Hazard: (if dam should fail completely)*

1. Minor _____ 2. Moderate ✓

3. Severe _____ 4. Disastrous _____

*This rating may change as land use changes (future development)

(6) Outlet Control: Automatic _____ Manual ✓

Operative ✓ yes: _____ no.

Comments: FLASHBOARDS IN EMERGENCY SPILLWAY CONTROL FLOW OF WATER OVER PRINCIPAL SPILLWAY.

(7) Upstream Face of Dam: Condition:

1. Good ✓ 2. Minor Repairs _____

3. Major Repairs _____ 4. Urgent Repairs _____

Comments: _____

DAM NO. 4-9-299-1

8) Downstream Face of Dam: Condition: 1. Good ✓ 2 Minor Repairs____
3. Major Repairs____ Urgent Repairs____

Comments:

9) Emergency Spillway: Condition: 1. Good ✓ 2. Minor Repairs____
3. Major Repairs____ 4. Urgent Repairs____

Comments:

10) Water level @ time of inspection ____ ft. above 0.5' below____
top of dam ____ Principal spillway ✓
other____

11) Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment ✓
Animal Burrows and Washouts
Damage to slopes or top of dam
Cracked or Damaged Masonry
Evidence of Seepage
Evidence of Piping
Erosion
Leaks
Trees and/or debris impeding flow
Clogged or blocked spillway
Other

4-9-299-1

-3-

(12) Remarks & Recommendations: (Fully Explain)

DAM IS IN GOOD CONDITION.

(13) Overall Condition:

1. Safe ✓
2. Minor repairs needed
3. Conditionally safe - major repairs needed
4. Unsafe
5. Reservoir impoundment no longer serves purpose

Recommend removal from inventory

DESCRIPTION OF DAM
DISTRICT #4

Submitted by FRANCIS H. PARE & ADAM Z PIZAN
Date 9-6-73

Dam No. 4-9-299-1
~~City~~/Town TOWNSEND 01469
Name of Dam TOWNSEND HARBOR DAM

1. Location: Topo Sheet No. 22A
Provide 8½" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: UNKNOWN Year/s of subsequent repairs NONE VISIBLE

3. Purpose of Dam: Water Supply ____. Recreational ✓
Irrigation ____. Other ____

4. Drainage Area: 60.6 SQ. Mi. [redacted] 38,400 ACRES.

5. Normal Ponding Area: 80 acres; Ave Depth 9'
Impoundment: 213 MIL gals: 640 acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir ____
i.e. summer homes etc. 3 HOMES ADJ. TO DAM

7. Dimensions of Dam: Length 80' Max. Height 10'
Slopes: Upstream Face VERT
Downstream Face "
Width across top 5'

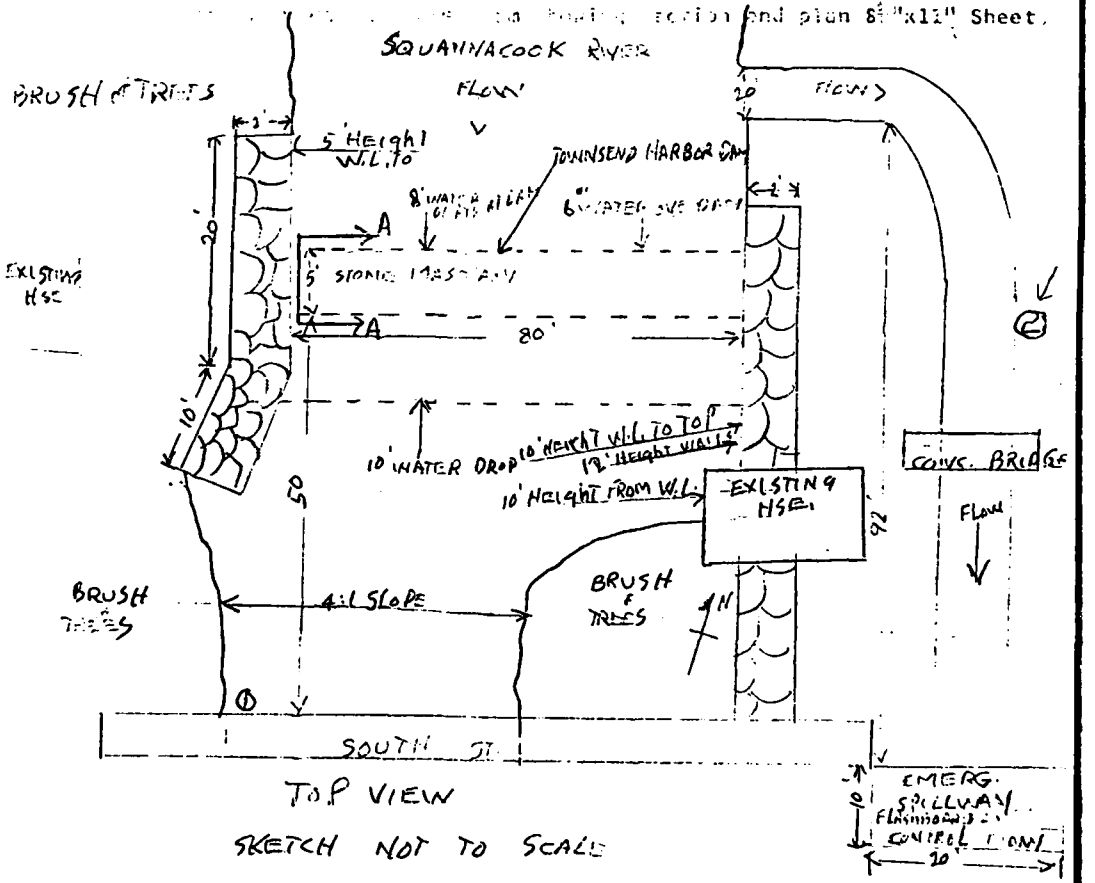
8. Classifications of Dam by Materials:
Earth ____. Conc. Masonary ____. Stone Masonary ✓
Timber ____. Rockfill ____. Other ____

9. A. Description of present land usage downstream of dam: 80 % rural; 20 % urban
B. Is there a storage area or flood plain downstream of dam: which could accommodate the impoundment in the event of a complete dam failure no ✓. yes ____.

DAM NO. 4-9-299-1

21 EST 3 PERSONS PER HOME
7
NONE
11
1 — WATER SYSTEM PLANT, EMER. SPILLWAY
1 OPERATING BD M ADJ. TO DAM, PARALLEL
NONE

and plan 8½"x11" Sheet.



TOP VIEW

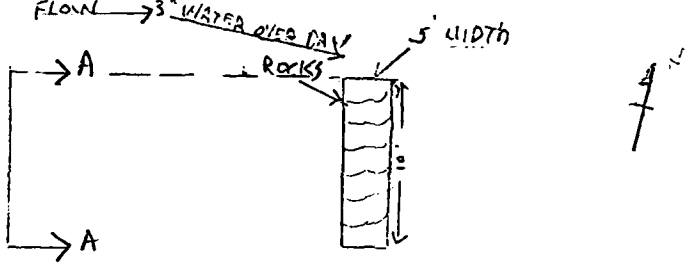
SKETCH NOT TO SCALE

DAM NO. 4-9-299-1

10.
Risk to life and property in event of complete failure.

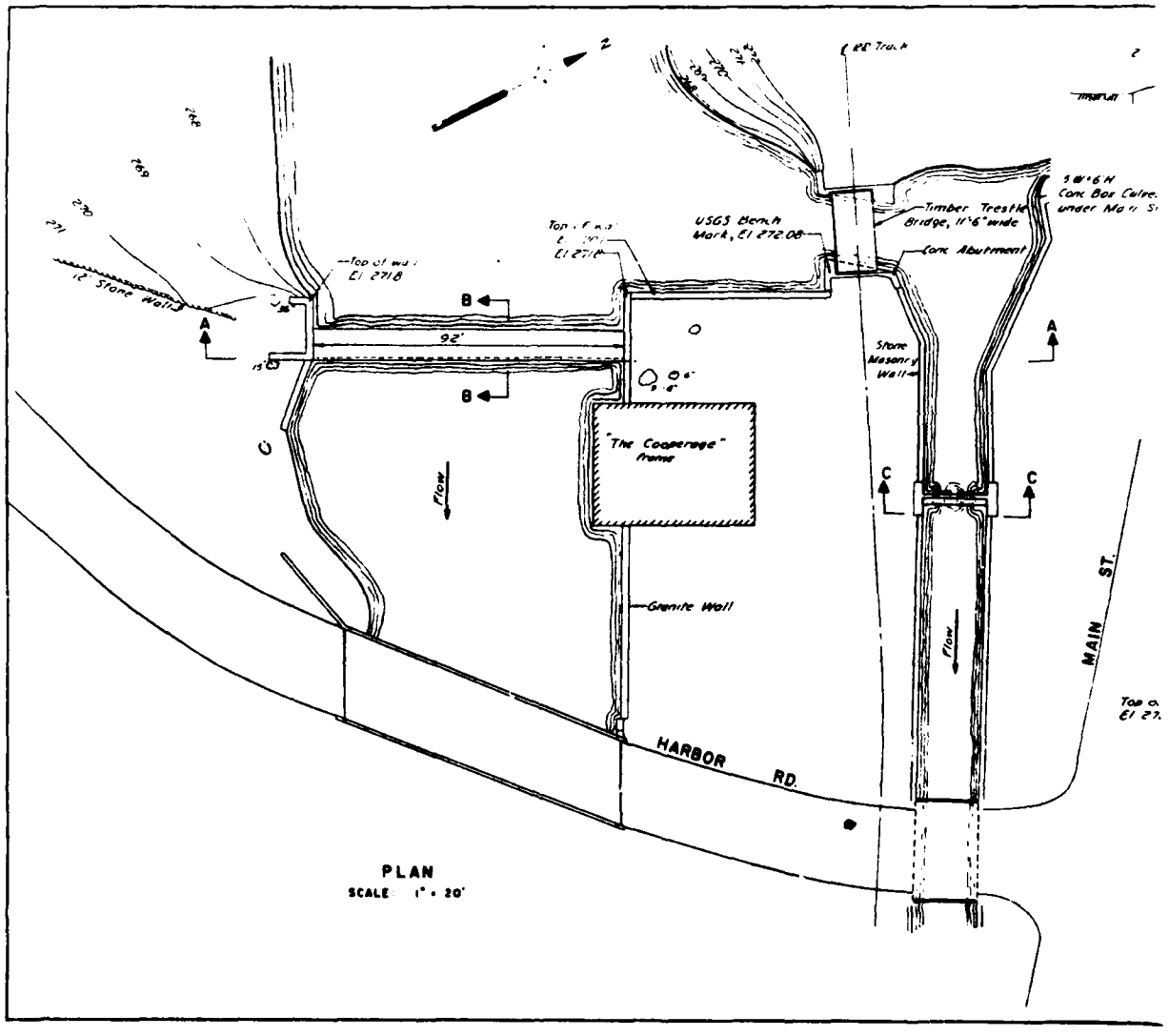
No. of people 21 EST. 3 PER. HOUSE
No. of homes 7.
No. of businesses NONE.
No. of industries 11. Type
No. of utilities 1 WATER SYSTEM PLANT, EMER. SPILLWAY
Railroads 1 OPERATING R.R., PARALLEL TO DAM
Other dams NONE.
Other

11.
Attach sketch of dam to this form showing section and plan 8½"X11" She



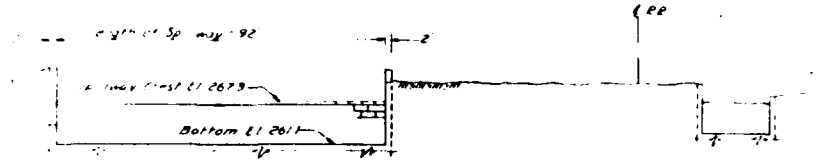
X SECTION AA

SKETCH NOT TO SCALE

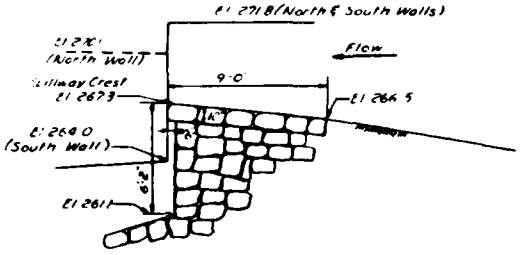


PLAN
SCALE 1" = 20'

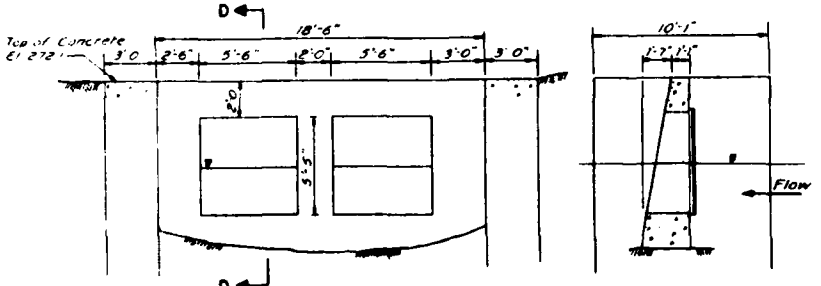
TOWNSEND



SECTION A-A
SCALE VERT 1" = 10'
HORZ 1" = 20'



SECTION B-B
SCALE $\frac{1}{4}$" = 1'-0"



SECTION C-C

SECTION D-D

SCALE $\frac{1}{4}$" = 1'-0"

DAM NO. E-1

NAME Townsend Harbor Dam

STREAM Squannacook River

LOCATION Townsend Harbor, Mass
Longitude 71°60'25" Latitude 42°39'09"

DRAINAGE AREA 6.06 Square Miles

TYPE Stone Masonry Overflow

GENERAL DIMENSIONS Length 92 ft, Height 6.2 ft

SPILLWAY Capacity 1290 cfs

OUTLET WORKS None

POND AREA 48± Acres

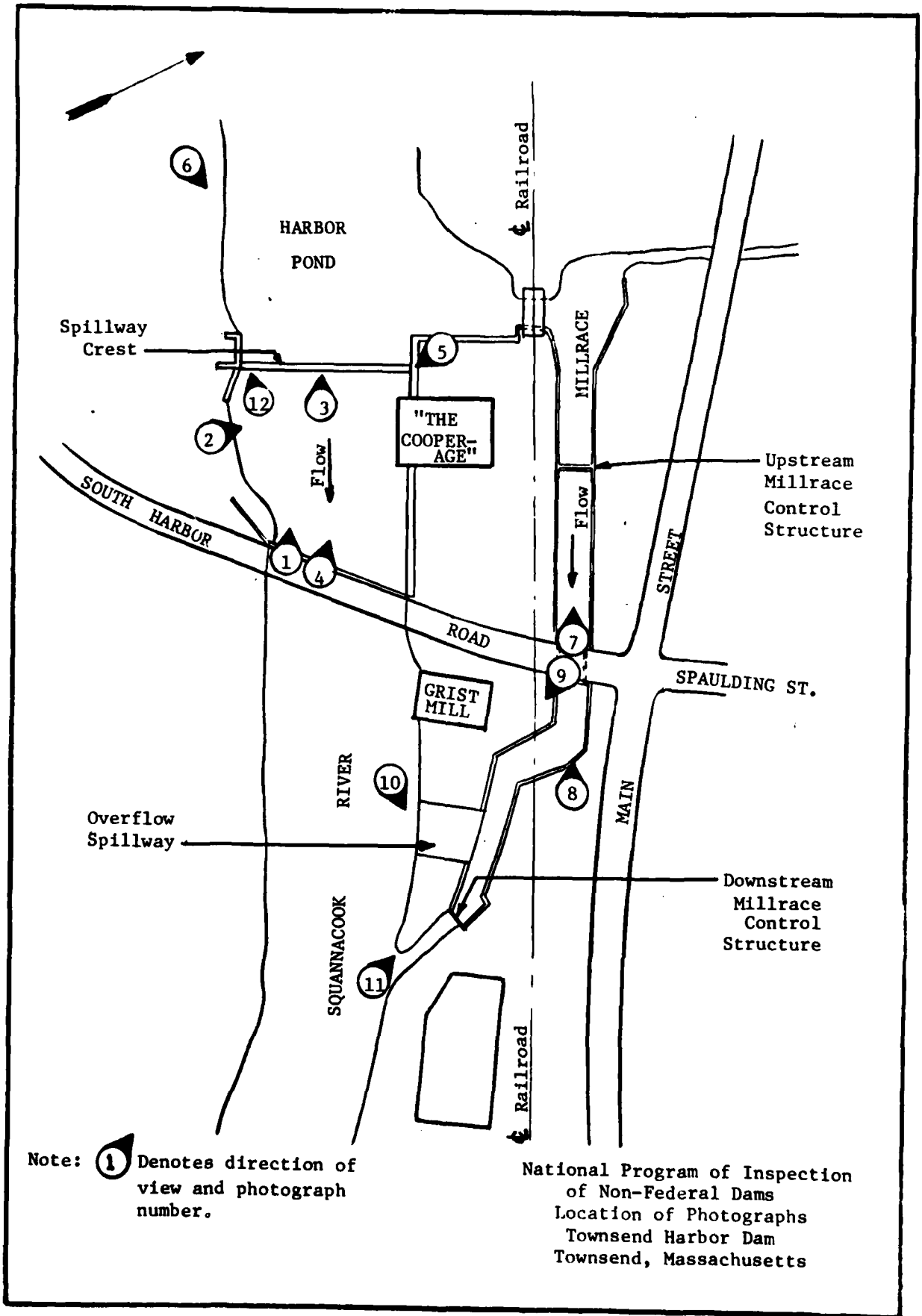
POND CAPACITY 93± Million Gallons

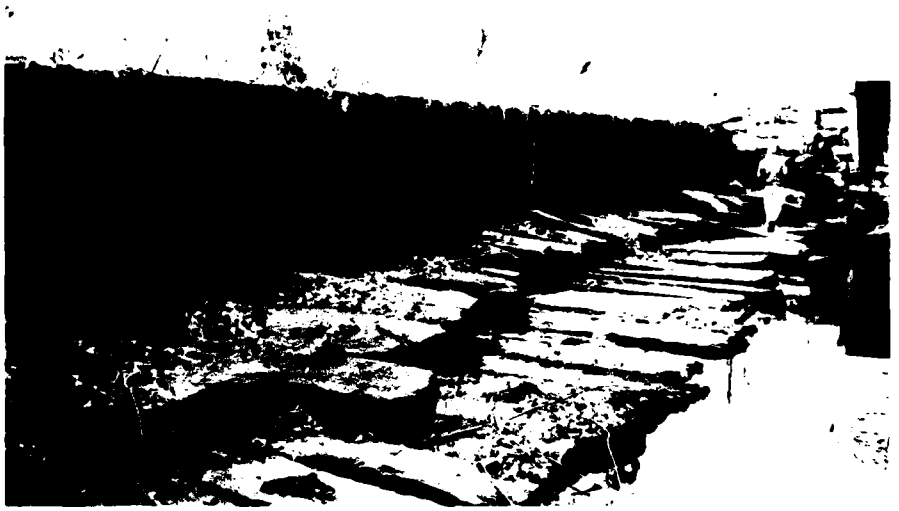
BENCH MARK USGS disc on southeast abutment of R.R. bridge as shown on plan

MAIN ST.

APPENDIX C

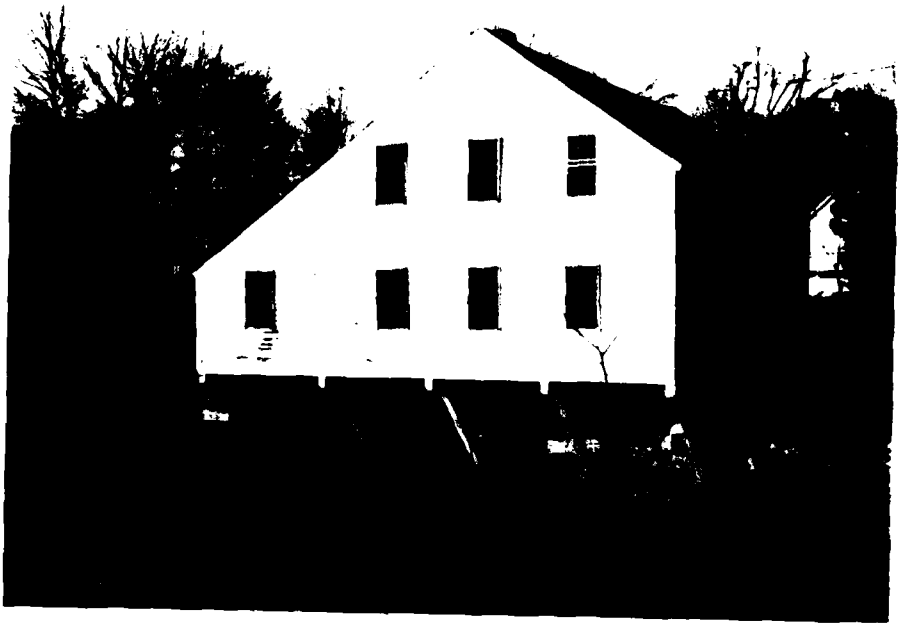
SELECTED PHOTOGRAPHS OF PROJECT


HARBOR
POND
Railroad
Spillway
Crest
MILLRACE
"THE
COOPER-
AGE"
Flow
Upstream
Millrace
Control
Structure
SOUTH HARBOR
ROAD
STREET
SPAULDING ST.
GRIST
MILL
RIVER
MAIN
Overflow
Spillway
Downstream
Millrace
Control
Structure
SQUANNACOOK
Railroad
Note: (1) Denotes direction of view and photograph number.
National Program of Inspection
of Non-Federal Dams
Location of Photographs
Townsend Harbor Dam
Townsend, Massachusetts



2. VIEW OF DAM FROM RIGHT DOWNSTREAM ABUTMENT.

3. KEY STONE IN DOWNSTREAM FACE OF DAM.

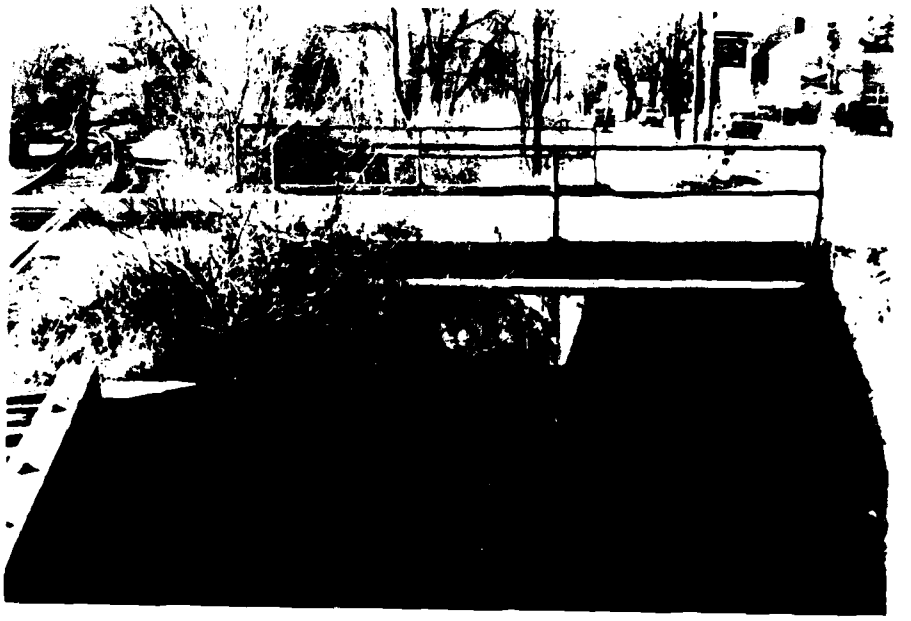


4. VIEW OF THE "COOPERAGE" FROM DOWNSTREAM RIGHT BANK OF SQUANNACOOK RIVER.

5. VIEW OF SOUTH HARBOR ROAD BRIDGE AND DOWNSTREAM CHANNEL FROM LEFT ABUTMENT.

6. VIEW OF LEFT ABUTMENT AND MILLRACE INLET WITH RAILROAD CROSSING.

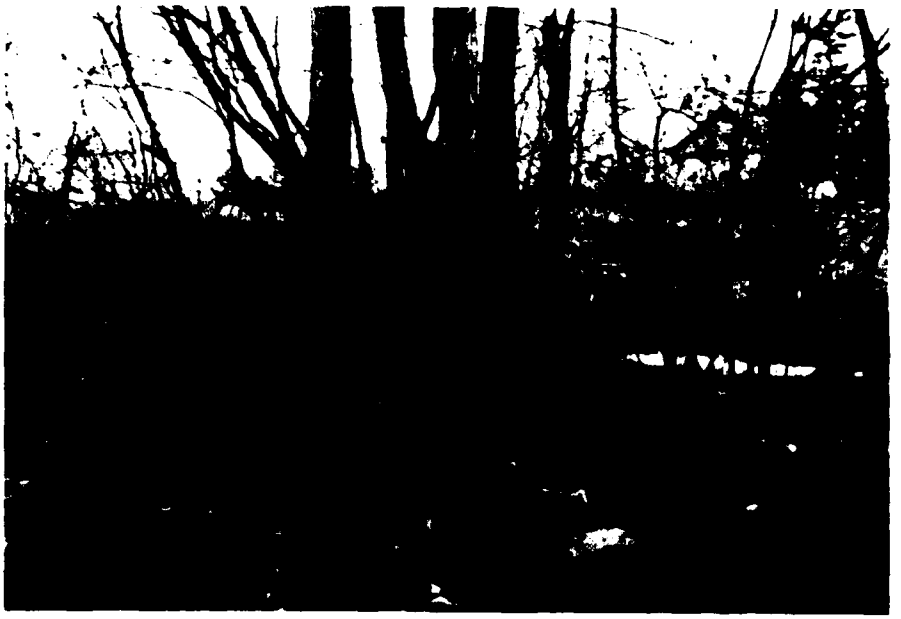
7. VIEW OF MILLRACE CONTROL STRUCTURE LOOKING EAST FROM SOUTH HARBOR ROAD.



8. DOWNSTREAM FACE OF SOUTH HARBOR ROAD OVER MILLRACE.

9. VIEW OF DOWNSTREAM END OF MILLRACE FROM SOUTH HARBOR ROAD. SECOND RAILROAD CROSSING IS IN FOREGROUND, MILLRACE OUTLET IN THE CENTER AND OVERFLOW SPILLWAY ALONG RIGHT CHANNEL WALL.

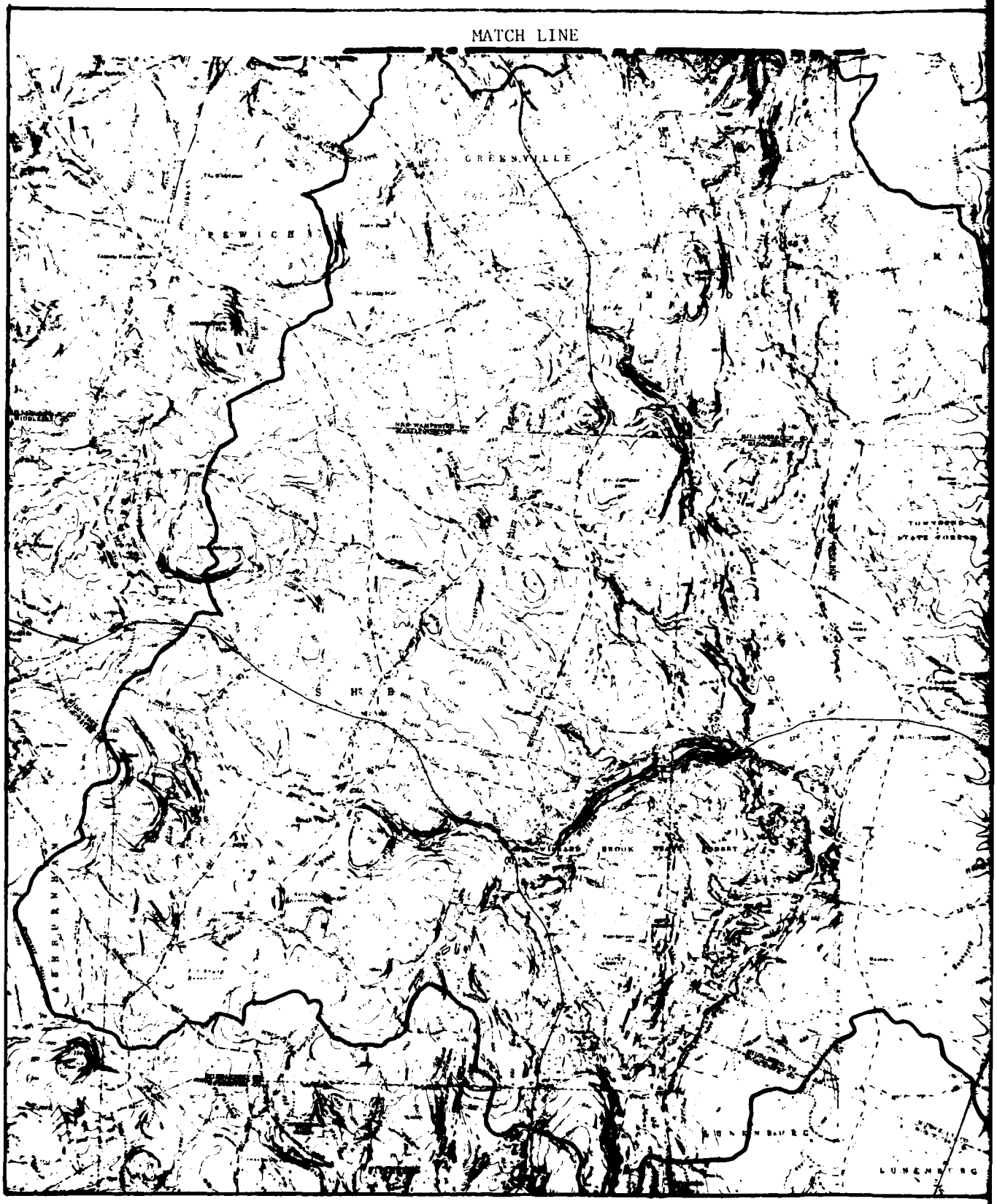
10. DOWNSTREAM FACE OF MILLRACE OVERFLOW SPILLWAY.

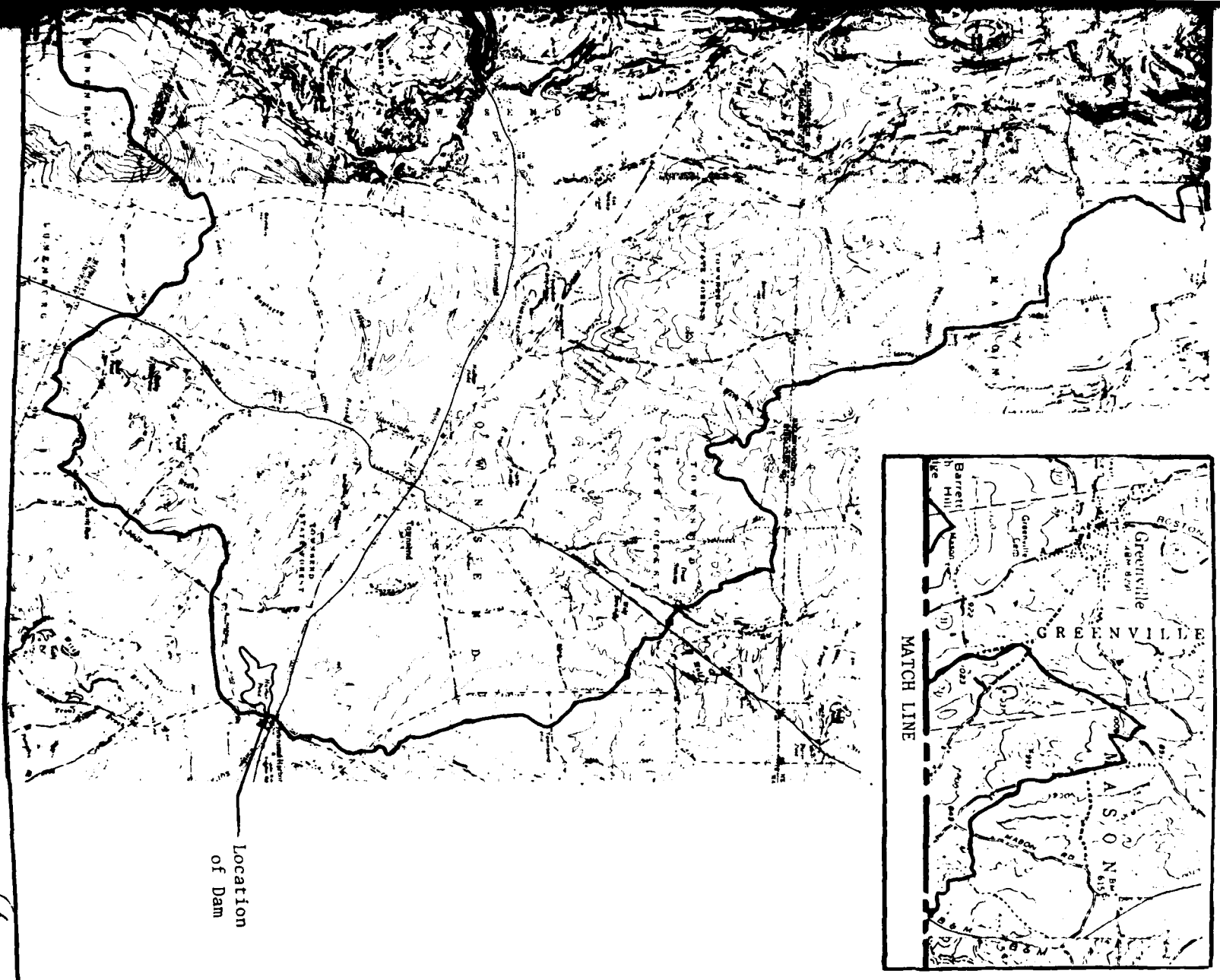


11. DOWNSTREAM FACE OF MILLRACE OUTLET.

12. SEEPAGE AT BOTTOM OF RIGHT WING WALL ADJACENT TO SPILLWAY.

APPENDIX D
OUTLINE OF DRAINAGE AREA AND
HYDRAULIC COMPUTATIONS


MATCH LINE
GREENVILLE

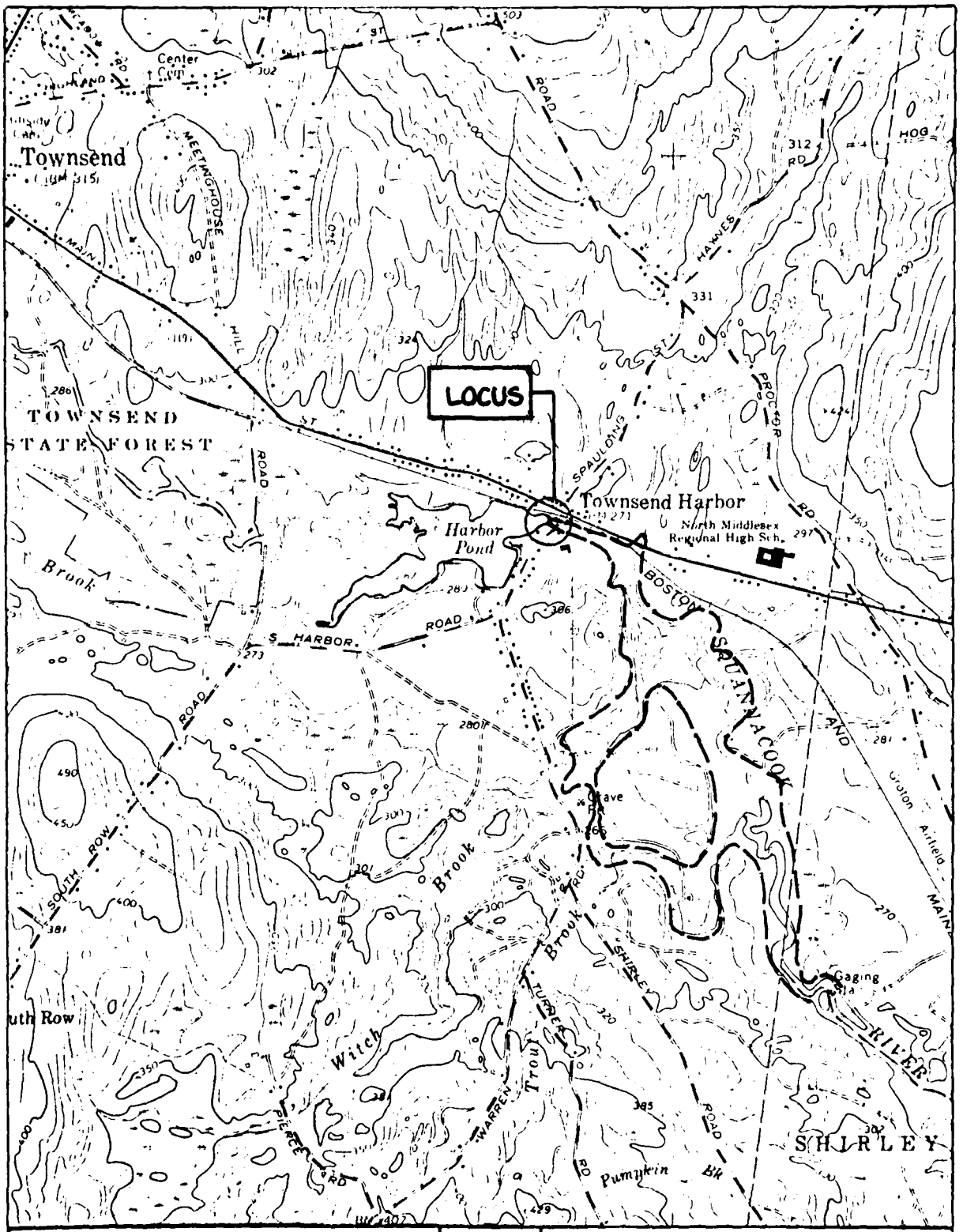


DAM TOWNSEND HARBOR DAM

IDENTIFICATION NO. MA 00138

DRAINAGE AREA MAP

APPROX. SCALE: 1" = 5200'



DAM TOWNSEND HARBOR DAM

IDENTIFICATION NO. MA 00138

DAM FAILURE IMPACT
AREA MAP
USGS QUADRANGLE
TOWNSEND, MASS. - N.H.

APPROX. SCALE: 1" = 2000'

APPENDIX D-2

SIZE CLASSIFICATION

Height: Top of dam El. 270.0
Toe of dam El. 259.0
11.0

Storage at top of dam:

Dead Storage (below spillway) 116 acre-feet
Surcharge Storage (to top of dam) 157 acre-feet
273 acre-feet

∴ Size Classification is SMALL

DAM FAILURE ANALYSIS

$$Q_{p_1} = \left[(8/27) W_b \sqrt{g}\, Y_o^{3/2}\right] + \left[0.6\, C L H^{3/2}\right]$$

$W_b = 37'$, $Y_o = 11'$, $C = 3.5$, $L = 92.2'$, $H = 2.7'$

$$Q_{p_1} = \left[(8/27)(37')(32.2)^{1/2}(11')^{3/2}\right] + \left[(0.6)(3.5)(92.2')(2.7')^{3/2}\right] = 3,130 \text{ cfs}$$

First downstream reach: From dam to South Harbor Road

Elevation	Discharge (cfs)	Storage (ac-ft)
260	0	0
262	295	1.5
264	905	3.0
266	1,730	4.4
268	2,715	5.9
270	3,850	7.4

Stage in 1st reach when outflow is 3,130 cfs is:

$$268 + \left[\frac{3,130 - 2,715}{3,850 - 2,715}\right]\left[270 - 268\right] = 268.7$$

Storage in 1st reach at El. 268.7 is:

$$5.9 + \left[\frac{268.7 - 268.0}{270.0 - 268.0}\right]\left[7.4 - 5.9\right] = 6.4 \text{ ac-ft} = V_1$$

$$Q_{p_2} = Q_{p_1}\left(1 - \frac{V}{S}\right) = 3,130\left(1 - \frac{6.4}{273}\right) = 3,060 \text{ cfs}$$

Stage in 1st reach when outflow is 3,060 cfs is:

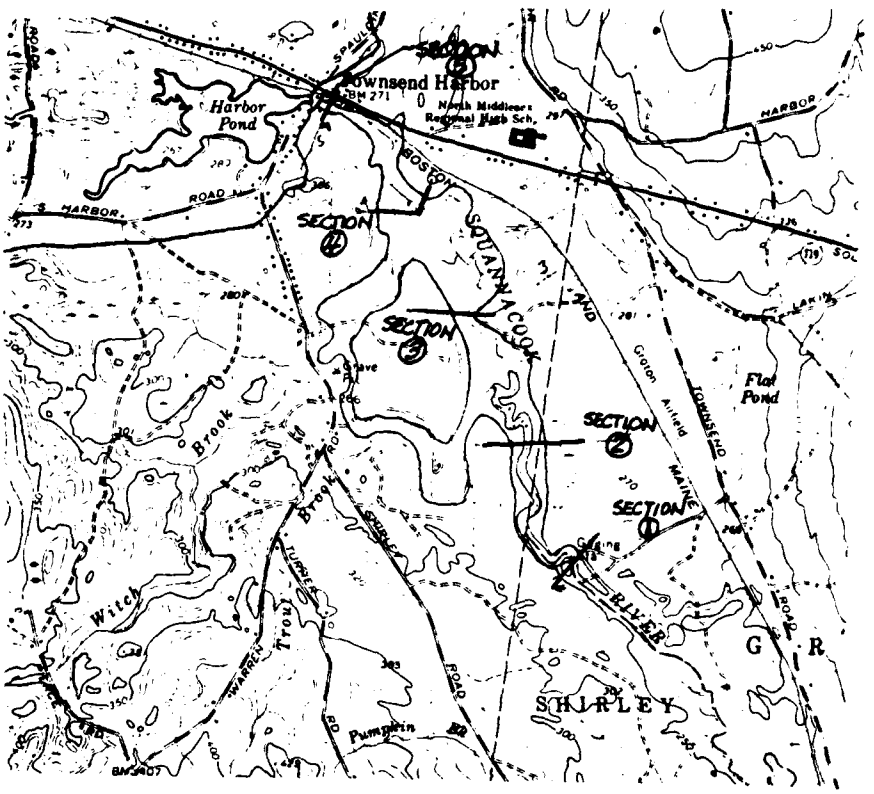
$$268 + \left[\frac{3,060 - 2,715}{3,850 - 2,715}\right]\left[270 - 268\right] = 268.6$$

CAMP DRESSER & McKEE INC

CLIENT COE
PROJECT Dam Inspections
DETAIL Townsend Harbor Dam

JOB NO 380-5-11
DATE CHECKED 6-6-79
CHECKED BY PFH

PAGE 1a of 1
DATE 6-6-79
COMPUTED BY JE



Location Cross Sections defining downstream reaches for the dam failure analysis

REACH NO. 1	Dam to South Harbor Lit. Section
REACH NO. 2	South Harbor Lit. Section to Millrace Outlet (X-Sect. 5)
REACH NO. 3	Millrace Outlet (X-Sect. 5) to X-Sect. 4
REACH NO. 4	X-Sect. 4 to X-Sect. 3
REACH NO. 5	X-Sect. 3 to X-Sect. 2
REACH NO. 6	X-Sect. 2 to USGS Gage No. 01096000 (X-Sect. 1)

Storage in 1st reach at El. 268.6 is:

$$5.9 + \left[\frac{268.6 - 268.0}{270.0 - 268.0}\right]\left[7.4 - 5.9\right] = 6.4 \text{ ac-ft} = V_2$$

$$V_3 = \frac{V_1 + V_2}{2} = 6.4 \text{ ac.-ft.}$$

$Q_{P_3} = Q_{P_2} =$ 3,060 cfs = Outflow from 1st reach

Stage in 1st reach when outflow is 3,060 cfs is 268.6. No buildings in the 1st reach would be affected by the dam-failure flood, but a building on the left bank just downstream of the bridge would be severely damaged and its occupants could be killed.

Second downstream reach: From South Harbor Rd. to Millrace Outlet

Discharge from millrace at dam failure (El. 270):

$$Q = \left[C_1 A_1 \sqrt{2g H_1}\right] + \left[C_2 L_2 H_2^{3/2}\right] + \left[C_3 L_3 H_3^{3/2}\right]$$

Outlet orifice: $C_1 = \left[1 + 0.4 R^{0.3} + \frac{0.0045 L}{R^{1.28}}\right]^{-1/2}$

$$C_1 = \left[1 + (0.4)\left(\frac{3.9' \times 2.8'}{(2)(3.9' + 2.8')}\right)^{0.3} + \left(\frac{0.0045 \times 2'}{0.82^{1.28}}\right)\right]^{-1/2} = 0.85$$

$A_1 = 3.9' \times 2.8' = 10.92$ □

$H_1 = 270.0 - 266.4 = 3.6'$

Emergency spillway: $C_2 = 2.8$, $L_2 = 18'$, $H_2 = 1.9'$

Right bank: $C_3 = 2.6$, $L_3 = 44.4'$, $H_3 = 0.8'$

$$Q = \left[(0.85)(10.92^{\square})(2 \times 32.2 \times 3.6')^{1/2}\right] + \left[(2.8)(18')(1.9')^{3/2}\right] + \left[(2.6)(44.4')(0.8')^{3/2}\right] = 360 \text{ cfs}$$

$Q_{P_1} = \left[Q_{P_3} \text{ From 1st reach}\right] + \left[360 \text{ cfs}\right] = 3,060 + 360 = 3,420$ cfs

Elevation	Discharge (cfs)	Storage (ac-ft)
260	0	0
262	500	1.1
264	1,700	2.2
266	3,560	3.3

Stage-Discharge-Storage Relationships at Channel Cross Section at Millrace Outlet

Stage in 2nd reach when outflow is 3,420 cfs is:

$$264 + \left[\frac{3,420 - 1,700}{3,560 - 1,700}\right]\left[266 - 264\right] = 265.8$$

Storage in 2nd reach at El. 265.8 is:

$$2.2 + \left[\frac{265.8 - 264}{266 - 264}\right]\left[3.3 - 2.2\right] = 3.2 \text{ ac.-ft.} = V_1$$

$Q_{P_2} = Q_{P_1}\left(1 - \frac{V_1}{S}\right) = 3,420\left(1 - \frac{3.2}{273}\right) = 3,380$ cfs

Stage in 2nd reach when outflow is 3,380 cfs is:

$$264 + \left[\frac{3,380 - 1,700}{3,560 - 1,700}\right]\left[266 - 264\right] = 265.8$$

Storage in 2nd reach at El. 265.8 = 3.2 ac.-ft. = V_2

$\therefore V_1 = V_2 = V_3 \Longrightarrow Q_{P_3} = Q_{P_2} =$ 3,380 cfs = Outflow from 2nd reach

No buildings in 2nd reach, except for the one just downstream of South Harbor Road referred to above, would be affected by dam-failure flood.

Third downstream reach: From Millrace Outlet to Cross Section 4

$Q_{P_1} = 3,380$ cfs (From 2nd reach)

Elevation	Discharge (cfs)	Storage (ac.-ft)
256.4	0	0
260.0	920	16.5
261.0	1,640	39.9
262.0	3,010	63.3
263.0	5,635	86.8

Stage in 3rd reach when outflow is 3,380 cfs is:

$$262 + \left[\frac{3,380 - 3,010}{5,635 - 3,010}\right]\left[263 - 262\right] = 262.1$$

Storage in 3rd reach at El. 262.1 is:

$$63.3 + \left[\frac{262.1 - 262.0}{263.0 - 262.0}\right]\left[86.8 - 63.3\right] = 65.6 \text{ ac.-ft.} = V_1$$

$Q_{P_2} = Q_{P_1}\left(1 - \frac{V_1}{S}\right) = 3,380\left(1 - \frac{65.6}{273}\right) = 2,570$ cfs

Stage in 3rd reach when outflow is 2,570 cfs is:

$$261 + \left[\frac{2,570 - 1,640}{3,010 - 1,640}\right]\left[262 - 261\right] = 261.7$$

Storage in 3rd reach at El. 261.7 is:

$$39.9 + \left[\frac{261.7 - 261.0}{262.0 - 261.0}\right]\left[63.3 - 39.9\right] = 56.3 \text{ ac.-ft.} = V_2$$

$V_3 = \frac{V_1 + V_2}{2} = \frac{65.6 + 56.3}{2} = 61.0$ ac.-ft

$Q_{P_3} = 3,380\left(1 - \frac{61}{273}\right) =$ 2,625 cfs = Outflow from 3rd reach

Stage in 3rd reach when outflow is 2,625 cfs is:

$$261 + \left[\frac{2,625 - 1,640}{3,010 - 1,640}\right]\left[262 - 261\right] = 261.7$$

No buildings in 3rd reach affected by dam-failure flood.

Fourth downstream reach: From Cross Section 4 to Cross Section 3

$Q_{p_1} = 2,625$ cfs (From 3rd reach)

Elevation	Discharge (cfs)	Storage (ac-ft)
252	0	0
254	310	48.7
255	910	73.0
256	1,960	97.4
257	3,540	121.7

Stage in 4th reach when outflow is 2,625 cfs is:

$$256 + \left[\frac{2,625 - 1,960}{3,540 - 1,960}\right]\left[257 - 256\right] = 256.4$$

Storage in 4th reach at El. 256.4 is:

$$97.4 + \left[\frac{256.4 - 256.0}{257.0 - 256.0}\right]\left[121.7 - 97.4\right] = 107.1 \text{ ac.-ft.} = V_1$$

$$Q_{p_2} = Q_{p_1}\left(1 - \frac{V}{S}\right) = 2,625\left(1 - \frac{107.1}{273}\right) = 1,595 \text{ cfs}$$

Stage in 4th reach when outflow is 1,595 cfs is:

$$255 + \left[\frac{1,595 - 910}{1,960 - 910}\right]\left[256 - 255\right] = 255.6$$

Storage in 4th reach at El. 255.6 is:

$$73.0 + \left[\frac{255.6 - 255.0}{256.0 - 255.0}\right]\left[97.4 - 73.0\right] = 87.6 \text{ ac.-ft.} = V_2$$

$$V_3 = \frac{V_1 + V_2}{2} = \frac{107.1 + 87.6}{2} = 97.4 \text{ ac.-ft.}$$

$$Q_{p_3} = 2,625\left(1 - \frac{97.4}{273}\right) = \underline{1,690 \text{ cfs} = \text{Outflow from 4th reach}}$$

Stage in 4th reach when outflow is 1,690 cfs is:

$$255 + \left[\frac{1,690 - 910}{1,960 - 910}\right]\left[256 - 255\right] = 255.7$$

No buildings in 4th reach affected by dam-failure flood.

Fifth downstream reach: From Cross Section 3 to Cross Section 2

Q_{p_1} = 1,690 cfs (From 4th reach)

Elevation	Discharge (cfs)	Storage (ac-ft)
247.7	0	0
250.0	250	5.8
251.0	635	49.6
252.0	1,460	93.5
253.0	2,995	137.4

Stage in 5th reach when outflow is 1,690 cfs is:

$$252 + \left[\frac{1,690 - 1,460}{2,995 - 1,460}\right]\left[253 - 252\right] = 252.2$$

Storage in 5th reach at El. 252.2 is:

$$93.5 + \left[\frac{252.2 - 252.0}{253.0 - 252.0}\right]\left[137.4 - 93.5\right] = 102.3 \text{ ac.-ft} = V_1$$

$$Q_{p_2} = Q_{p_1}\left(1 - \frac{V_1}{S}\right) = 1,690\left(1 - \frac{102.3}{273}\right) = 1,055 \text{ cfs}$$

Stage in 5th reach when outflow is 1,055 cfs is:

$$251 + \left[\frac{1,055 - 635}{1,460 - 635}\right]\left[252 - 251\right] = 251.5$$

Storage in 5th reach at El. 251.5 is:

$$49.6 + \left[\frac{251.5 - 251.0}{252.0 - 251.0}\right]\left[93.5 - 49.6\right] = 71.6 \text{ ac.-ft.} = V_2$$

$$V_3 = \frac{V_1 + V_2}{2} = \frac{102.3 + 71.6}{2} = 87.0 \text{ ac.-ft.}$$

$$Q_{p_3} = 1,690\left(1 - \frac{87}{273}\right) = \underline{1,150 \text{ cfs} = \text{Outflow from 5th reach}}$$

Stage in 5th reach when outflow is 1,150 cfs is:

$$251 + \left[\frac{1,150 - 635}{1,460 - 635}\right]\left[252 - 251\right] = 251.6$$

A building on Trout Brook in the right flood plain of the Squannacook River would probably be affected by a dam failure flood stage at El. 251.6.

Sixth downstream reach: At USGS Gage No. 01096000

Q_{p_1} = 1,150 cfs (From 5th reach)

Elevation	Discharge (cfs)	Storage (ac.-ft.)
244.3	0	0
249.0	640	19.5
250.0	1,220	23.6

} Elevation-Discharge Relationships From Annual USGS Publications of Surface Water Records

Stage in 6th reach when outflow is 1,150 cfs is:

$$249 + \left[\frac{1,150 - 640}{1,220 - 640}\right]\left[250 - 249\right] = 249.9$$

Storage in 6th reach at El. 249.9 is:

$$19.5 + \left[\frac{249.9 - 249.0}{250.0 - 249.0}\right]\left[23.6 - 19.5\right] = 23.2 \text{ ac.-ft.} = V_1$$

$$Q_{P_2} = Q_{P_1}\left(1 - \frac{V_1}{S}\right) = 1,150\left(1 - \frac{23.2}{273}\right) = 1,050 \text{ cfs}$$

Stage in 6th reach when outflow is 1,050 cfs is:

$$249 + \left[\frac{1,050 - 640}{1,220 - 640}\right]\left[250 - 249\right] = 249.7$$

Storage in 6th reach at El. 249.7 is:

$$19.5 + \left[\frac{249.7 - 249.0}{250.0 - 249.0}\right]\left[23.6 - 19.5\right] = 22.4 \text{ ac.-ft} = V_2$$

$$V_3 = \frac{V_1 + V_2}{2} = \frac{23.2 + 22.4}{2} = 22.8 \text{ ac.-ft.}$$

$$Q_{P_3} = 1,150\left(1 - \frac{22.8}{273}\right) = 1,055 \text{ cfs} = \text{Outflow from 6th reach}$$

Stage in 6th reach when outflow = 1,055 cfs is:

$$249 + \left[\frac{1055 - 640}{1,220 - 640}\right]\left[250 - 249\right] = 249.7$$

No buildings in 6th reach affected by dam-failure flood.

A flow of 1,055 cfs is expected to be equaled or exceeded at the gage an average of once every 17 months. There is a 70 percent chance that it will be equaled or exceeded in any given year. This flow is not expected to cause any damage downstream of the gage.

The dam failure analysis indicates that 2 buildings may be affected by the dam failure flood. The estimated potential loss of life is a few persons.

∴ SIGNIFICANT HAZARD

TEST FLOOD: 100-Yr. to ½ PMF Range, Use ¼ PMF

From COE Guideline Curves for Rolling Terrain use 1,100 cfs/mi²

Test Flood = (¼)(1,100 cfs/mi²)(58.3 mi²) = 16,000 cfs

Millrace Discharges

1. Outlet below El. 269.2

Weir with end contractions $Q = C_e L_e H_e^{3/2}$

Length = 3.9'

b = millrace width = 12' ±

P = 266.4 - 263.1 = height from millrace invert to weir crest

$K_H = 0.003$

$L/b = (3.9') \div (12') = 0.3 \quad \therefore K_L = 0.009 \Rightarrow L_e = 3.909$

Elev.	H	H/P	C_e	H_e	Q
266.4	0	0	0	0	0
267.3	0.9	0.27	3.15	0.903	11
268.1	1.7	0.52	3.18	1.703	28

2. Outlet above El. 269.2

Orifice operating under inlet control $Q = CA\sqrt{2gH}$

From page 2 of 14, above, $Q = (0.85)(10.92^{(1)})(8.02)(H)^{1/2}$

Elev	H	Q
269.2	2.8	125
270.1	3.7	143
270.2	3.8	145
271.0	4.6	160
272.0	5.6	175
273.0	6.6	190

3. Overflows above El. 268.1

		Overflow Spillway		Side Walls at Overflow Spillway		Weir Above Millrace Outlet		
Weir length		18'		44.4'		15'		
Weir crest elev		268.1		269.2		270.2		
Weir "C"		2.8		2.6		3.5		Total
	Elev.	H	Q	H	Q	H	Q	Flow
	268.1	0	0	0	0	0	0	0
	269.2	1.1	60	0	0	0	0	60
	270.1	2.0	145	0.9	100	0	0	245
	270.2	2.1	155	1.0	115	0	0	270
	271.0	2.9	250	1.8	280	0.8	40	570
	272.0	3.9	390	2.8	540	1.8	125	1,055
	273.0	4.9	545	3.8	855	2.8	245	1,645

Discharges at Millrace Entrance (Railroad Bridge)

1. Open-channel flow below El. 269.7

   The discharge is equal to that at the downstream end of the millrace, but the pond water surface elevation equals the water surface elevation at the downstream end of the millrace plus the millrace head loss.

2. Orifice flow above El. 269.7, operating under outlet control.

   Area = 16.3' × 6.6' = 107.6 ft^2

   Wetted Perimeter = (2)(16.3' + 6.6') = 45.8'

   $R = (107.6) \div (45.8) = 2.35$

   $K = 1.5 + \frac{29 n^2 L}{R^{4/3}} = 1.5 + \frac{(29)(0.020)^2(11.5')}{(2.35)^{4/3}} = 1.54$

   $Q_o = A\sqrt{\frac{2gH}{K}} = (107.6)\sqrt{\frac{(64.4)(H)}{(1.54)}} = 695.8\sqrt{H}$

   H is the difference between water surface elevation, upstream and downstream of the railroad bridge.

① Water Surface Elevation at Downstream End of Millrace	② Millrace Discharge (Previous Page)	③ Millrace Head Loss (Estimated)	④ Water Surface Elevation Downstream of RR Bridge ① + ③	⑤ "H" in Orifice Equation (② ÷ 695.8)^2	⑥ * Water Surface Elevation Upstream of RR Bridge ④ + ⑤
266.4	0	0	266.4		266.4
267.3	11	0.2	267.5	Open-	267.5
268.1	28	0.2	268.3	Channel	268.3
269.2	185	0.2	269.4	Flow	269.4
270.1	390	0.5	270.6	0.31	270.9
270.2	415	0.5	270.7	0.36	271.1
271.0	730	0.8	271.8	** 1.10	272.9
272.0	1,230	1.0	273.0	** 1.80	274.8
273.0	1,835	1.2	274.2	** 2.50	276.7

* Water surface elevation of Harbor Pond.

** Value of "H" determined by balancing orifice and weir flow. See next page.

3. Weir flow above El. 272.6 (railroad track)

   Weir length = 35'

   Weir "C" = 2.6

   $Q_w = C L H_1^{3/2}$

   H_1 is the difference between the pond elevation and the weir crest (El. 272.6).

CAMP DRESSER & McKEE
Environmental Engineers
Boston, Mass.

CLIENT COE
PROJECT Dam Inspection
DETAIL Townsend Harbor Dam

JOB NO 380-5-11
DATE CHECKED 6-6-79
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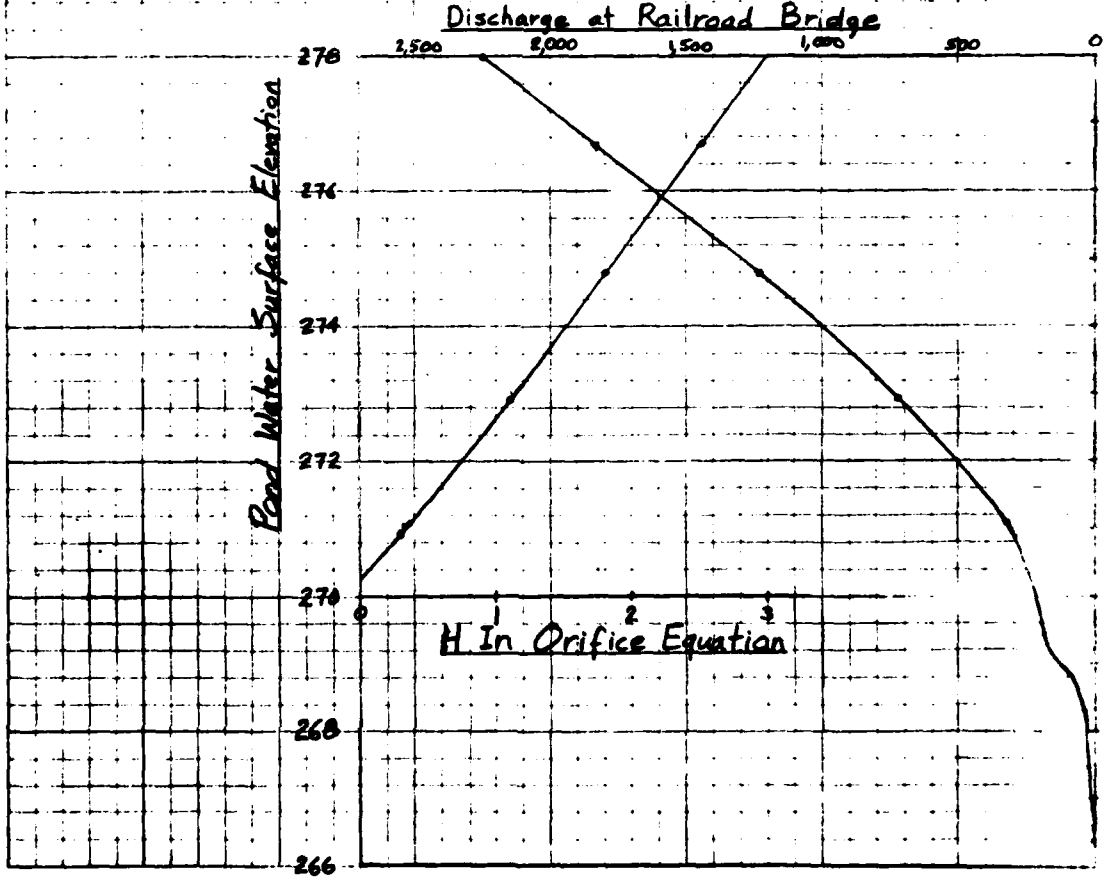
COMPUTED BY PEH

Balance orifice and weir flow at railroad bridge:

$Q_T = Q_o + Q_w = 695.8\sqrt{H} + 91(H)^{3/2}$

DSEL = water surface elevation downstream of railroad bridge
USEL = pond water surface elevation (upstream of RR bridge)

① Q_T	② DSEL	③ H (①/695.8)^2	④ USEL (②+③)	⑤ H (④-272.6)	⑥ Q_w 91×(⑤)$^{3/2}$	⑦ Q_o (①-⑥)	⑧ Computed H (⑦/695.8)^2	⑨ Try New H
730	271.8	1.1	272.9	0.3	15	715	1.1	OK
1,230	273.0	3.1	276.1	3.5	595	635	0.8	1.8
		1.8	274.8	2.2	295	935	1.8	OK
1,835	274.2	2.0	276.2	3.6	620	1,215	3.1	2.5
		2.5	276.7	4.1	755	1,080	2.4	OK

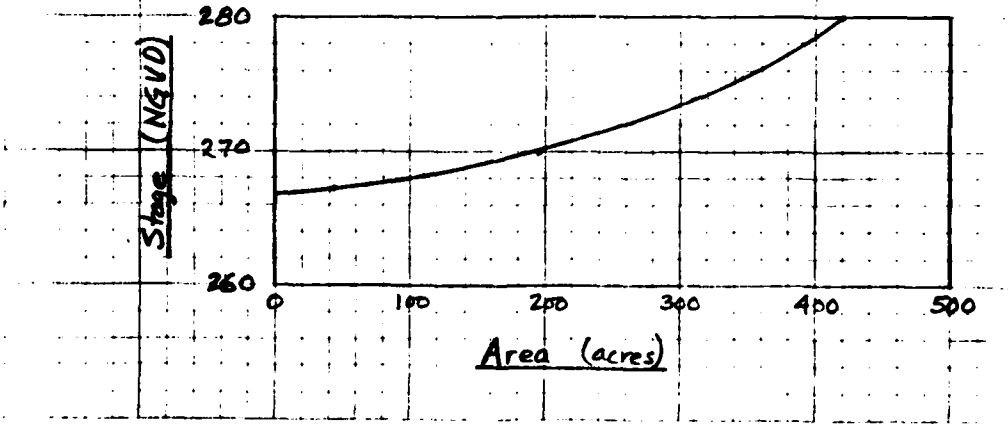


Stage-Discharge Characteristics of Harbor Pond

	Spillway		Right Embankment			Left Embankment		Railroad Bridge	Total Discharge
Weir C	3.5		2.3			2.6		See graph on page 9.	
Weir Length	92.2'		Varies			57'			
Weir Crest Elev.	267.3		270.0			270.1			
Elev.	H (ft)	Q (cfs)	H (ft)	L (ft)	Q (cfs)	H (ft)	Q (cfs)	(cfs)	(cfs)
266.4	0	0	0	0	0	0	0	0	0
267.0	0	0	0	0	0	0	0	5	5
268.0	0.7	190	0	0	0	0	0	20	210
269.0	1.7	715	0	0	0	0	0	150	865
270.0	2.7	1,430	0	0	0	0	0	225	1,655
271.0	3.7	2,300	1.0	23.5	55	0.9	125	410	2,890
272.0	4.7	3,290	2.0	43.0	280	1.9	390	500	4,460
273.0	5.7	4,390	3.0	56.0	670	2.9	730	750	6,540
274.0	6.7	5,595	4.0	68.0	1,250	3.9	1,140	1,000	8,985
275.0	7.7	6,895	5.0	81.0	2,085	4.9	1,605	1,300	11,885
276.0	8.7	8,280	6.0	93.5	3,160	5.9	2,120	1,610	15,170
277.0	9.7	9,750	7.0	106.0	4,515	6.9	2,680	1,940	18,885
278.0	10.7	11,295	8.0	119.0	6,195	7.9	3,290	2,250	23,030

Stage - Storage - Area Characteristics of Harbor Pond

Elev.	Area (acres)	Avg. Area (acres)	H (ft)	Storage Above Spillway (acre-ft)
267.3	43.5			0
270.0	197.4	120.4	2.7	325
280.0	421.5	309.4	10.0	3,419



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Boston, Mass.

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DETAIL Townsend Harbor Dam

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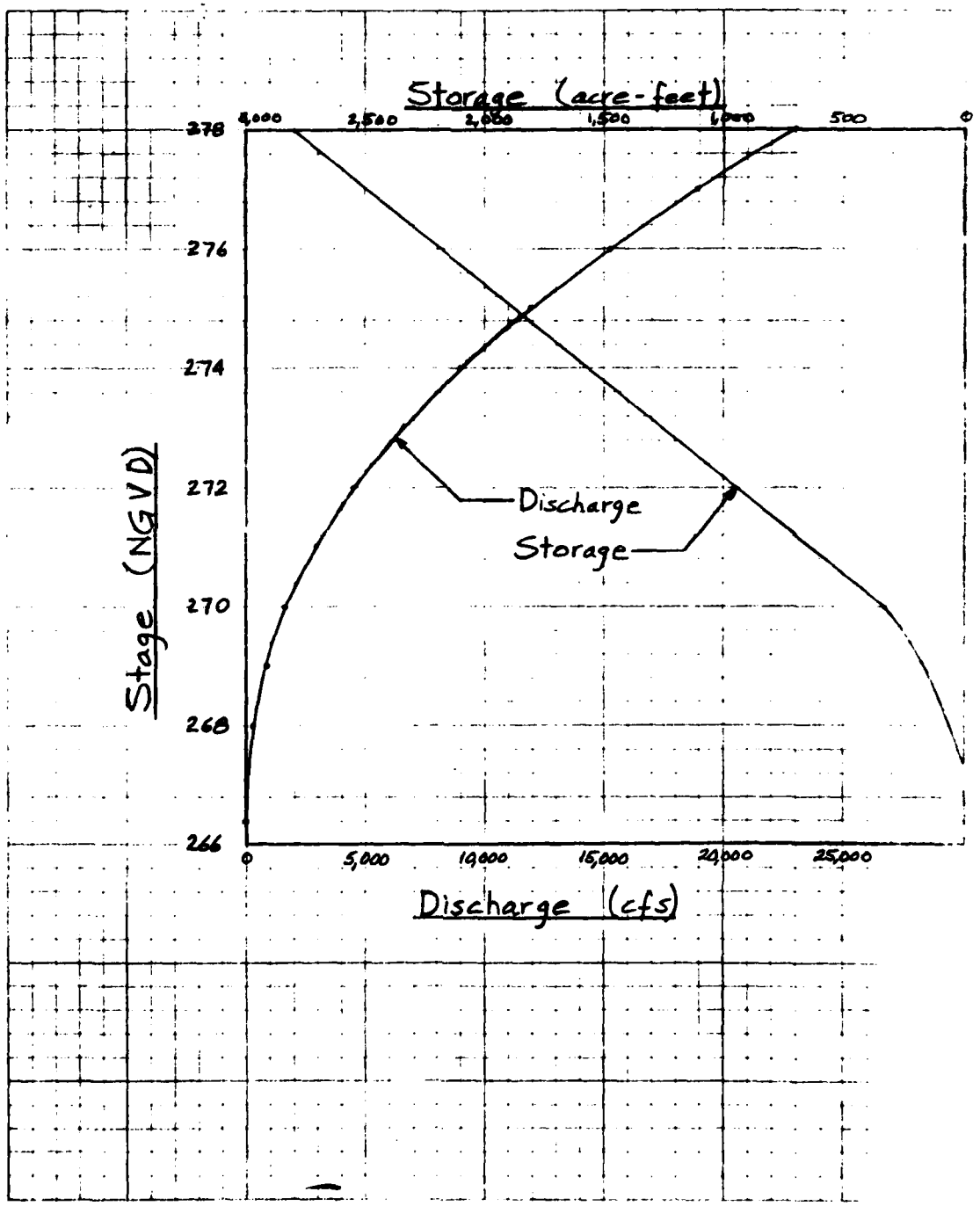


Surcharge - Storage Routing Through Harbor Pond

Q_{P_1} = Test flood inflow = 16,000 cfs (From page 6)

Stage when outflow is 16,000 cfs is El. 276.2
Storage at El. 276.2 is 2,243 ac.-ft.

$$\text{Runoff Volume} = \frac{2,243 \text{ ac.-ft.}}{(58.25 \text{ mi}^2)(53.3 \frac{\text{ac.-ft.}}{\text{inch-mi}^2})} = 0.72\text{" runoff}$$

1/4 PMF runoff volume = 5" ±

$$Q_{P_2} = Q_{P_1}\left(1 - \frac{V_1}{S}\right) = 16,000\left(1 - \frac{0.72"}{5"}\right) = 13,700 \text{ cfs}$$

Stage when outflow is 13,700 cfs is El. 275.6
Storage at El. 275.6 is 2,058 ac.-ft.

$$\text{Avg. Storage} = \left[\frac{2,243 + 2,058}{2}\right] = 2,150 \text{ ac.-ft.}$$

Stage when storage is 2,150 ac.-ft. is 275.9
Outflow at El. 275.9 is 14,840 cfs

Tailwater Analysis

Determine tailwater elevation at upstream face of South Harbor Road bridge. The river channel discharge between the dam and the bridge comes principally from the spillway and right embankment.

$$Q = \left[(3.5)(92.2')(275.9 - 267.3)^{3/2}\right] + \left[(2.3)(92.2')(275.9 - 270.0)^{3/2}\right] = 11,180 \text{ cfs}$$

Water surface elevation at downstream face of South Harbor Road bridge is approximately the same as that at the confluence of the millrace discharge channel with the river channel, at which point the river flow is the entire test flood outflow, 14,840 cfs.

At millrace outlet:

Elevation	Discharge (cfs)
270	9,535
271	10,070
272	11,485
273	13,670
274	16,600

Stage when discharge is 14,840 cfs is:

$$273 + \left[\frac{14,840 - 13,670}{16,600 - 13,670}\right]\left[274 - 273\right] = 273.4$$

Balance orifice and weir flow at South Harbor Road bridge

1. Orifice under outlet control (Crown El. 270.4)

Area = (10.4' × 83') = 863.2 □

Wetted Perimeter = (2)(10.4' + 83') = 186.8'

R = (863.2) ÷ (186.8) = 4.62'

Length = 30'

n = 0.050

$$K = 1.5 + \frac{29 n^2 L}{R^{4/3}} = 1.5 + \frac{(29)(0.050)^2(30')}{(4.62)^{4/3}} = 1.78$$

$$Q_o = A\sqrt{\frac{2g H_o}{K}} = 863.2\,\square\sqrt{\frac{(64.4)H_o}{1.78}} = 5{,}192\sqrt{H_o}$$

2. Weir at El. 274: Length = 200', C = 3.0, $Q_w = C L H_w^{3/2}$

Stage - Area Relationships:

Elevation	Area (□)
270.4 - 274	863.2
275	1,063.2
276	1,263.2
277	1,463.2

① Assumed Q_w	② H_w	③ USEL	④ Area at USEL	⑤ Velocity	⑥ Velocity Head	⑦ Energy Grade Line	⑧ H_o	⑨ Q_o	⑩ Computed Q_w	⑪ Assume New Q_w
	①/600 $^{2/3}$	274 + ②	From Table Above	11,180/④	⑤²/2g	③ + ⑥	⑦ - 274	5192 - ⑧$^{1/2}$	11,180 - ⑨	
1,330	1.7	275.7	1,203.2	9.3	1.3	277.0	3.6	9,850	1,330	OK
For Submerged Conditions: (See next page)										
				9,530/④			⑦ - 273.3		9,530 - ⑨	
540	0.9	274.9	1,043.2	9.1	1.3	276.2	2.9	8,840	690	560
560	1.0	275.0	1,063.2	9.0	1.3	276.3	3.0	8,990	540	OK

Tailwater El. 275.7 indicates that the dam is submerged. In order to account for submergence at the dam, reduce the discharges at the spillway and right embankment. Assume submergence ratio = 0.75 Reduce free-flow discharges 40%

Elev.	Spillway Free Discharge	Spillway Submerged Discharge	Right Embankment Free Discharge	Right Embankment Submerged Discharge	Total Submerged Discharge	Left Embankment	Railroad Bridge	Total Discharge
273	4,390	2,635	670	400	3,035	730	750	4,515
274	5,595	3,355	1,250	750	4,105	1,140	1,000	6,245
275	6,895	4,135	2,085	1,250	5,385	1,605	1,300	8,290
276	8,280	4,970	3,160	1,895	6,865	2,120	1,610	10,595
277	9,750	5,850	4,515	2,710	8,560	2,680	1,940	13,180
278	11,295	6,780	6,195	3,720	10,500	3,290	2,250	16,040

Surcharge-Storage Routing With Submergence

Stage when outflow is 16,000 cfs is El. 278
Storage at El. 277.8 is 2,800 ac.-ft.

$$\text{Runoff Volume} = \frac{2,800}{(58.25)(53.3)} = 0.9\text{" runoff}$$

$$Q_{p_2} = 16,000\left(1 - \frac{0.9"}{5"}\right) = 13,120 \text{ cfs}$$

Stage when outflow is 13,120 cfs is El. 277
Storage at El. 277 is 2,491 ac.-ft.

$$\text{Avg. Storage} = \left[\frac{2,800 + 2,491}{2}\right] = 2,646 \text{ ac.-ft.}$$

Stage when storage is 2,646 ac.-ft. is 277.5
Outflow at El. 277.5 is 14,610 cfs

Tailwater Analysis With Submergence

Stage at downstream face of South Harbor Road bridge when discharge at confluence with millrace outlet is 14,710 cfs is:

$$273 + \left[\frac{14,610 - 13,670}{16,600 - 13,670}\right]\left[274 - 273\right] = 273.3$$

Discharge at spillway and right embankment:

$$Q = 8,560 + \left[\frac{277.5 - 277.0}{278.0 - 277.0}\right]\left[10,500 - 8,560\right] = 9,530 \text{ cfs}$$

Tailwater elevation for submerged conditions is El. 275.0. (See tabular balance of orifice and weir flow on previous page.)

Check submergence ratio: $\frac{(275.0 - 267.3)}{(277.5 - 267.3)} = 0.76$ OK

Test-Flood Outflow = 14,610 cfs at El. 277.5

The test flood overtops the dam by 7.5' and the spillway by 10.2'.

Tailwater Elevation is 275.0

Spillway capacity at test flood elevation:

$$5,850 + \left[\frac{277.5 - 277.0}{278.0 - 277.0}\right]\left[6,780 - 5,850\right] = 6,320 \text{ cfs}$$

APPENDIX E
INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

INVENTORY OF DAMS IN THE UNITED STATES

IDENTITY NUMBER	DIVISION	STATE	COUNTY	CONGR DIST	STATE	COUNTY	CONGR DIST	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE DAY MO YR
[illegible] 14[illegible]	NED	MA	017	05				TOWNSEND HARBOR DAM	4239.2	7140.4	22JUN79

POPULAR NAME	NAME OF IMPOUNDMENT
SPAULDING DAM	HARBOR POND

REGION BASIN	RIVER OR STREAM	NEAREST DOWNSTREAM CITY TOWN VILLAGE	DIST FROM DAM (MI)	POPULATION
01 05	SQUANNACOOK RIVER	TOWNSEND	0	5125

TYPE OF DAM	YEAR COMPLETED	PURPOSES	STRUCT HEIGHT (FT)	HYDRAU HEIGHT (FT)	IMPOUNDING CAPACITIES MAXIMUM (ACRE-FT)	NORMAL (ACRE-FT)	DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
GRREPG	1570	O	11	11	273	115	NED	N	N	N	N	22JUN79

REMARKS

[illegible] CONTROL

D/S HAS	SPILLWAY TYPE	WIDTH	MAXIMUM DISCHARGE (FT)	VOLUME OF DAM (CY)	POWER CAPACITY	NAVIGATION LOCKS
2	[illegible] 0	92	1450			

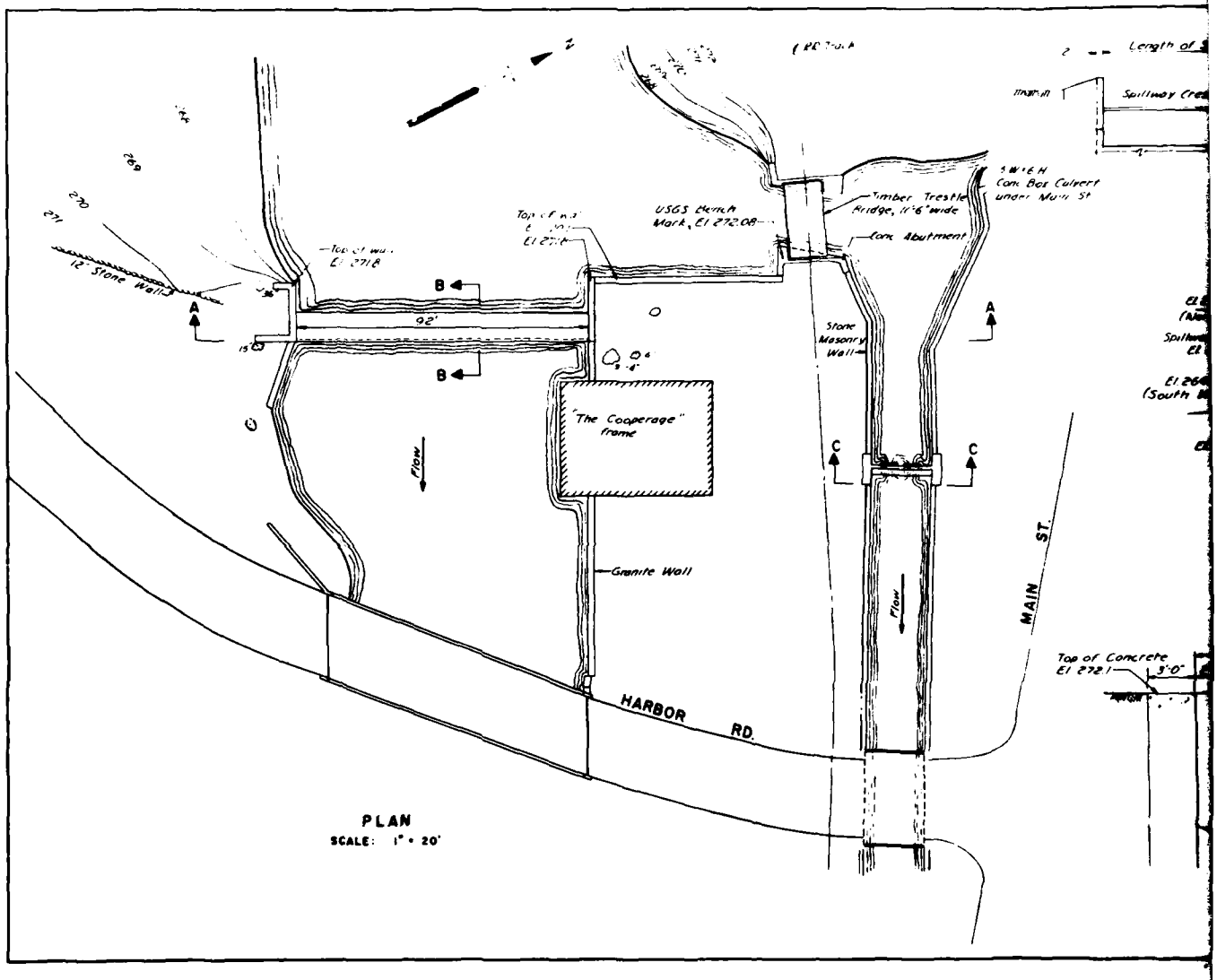
OWNER	ENGINEERING BY	CONSTRUCTION BY
[illegible] LINGSWORTH AND VOSE		

REGULATORY AGENCY

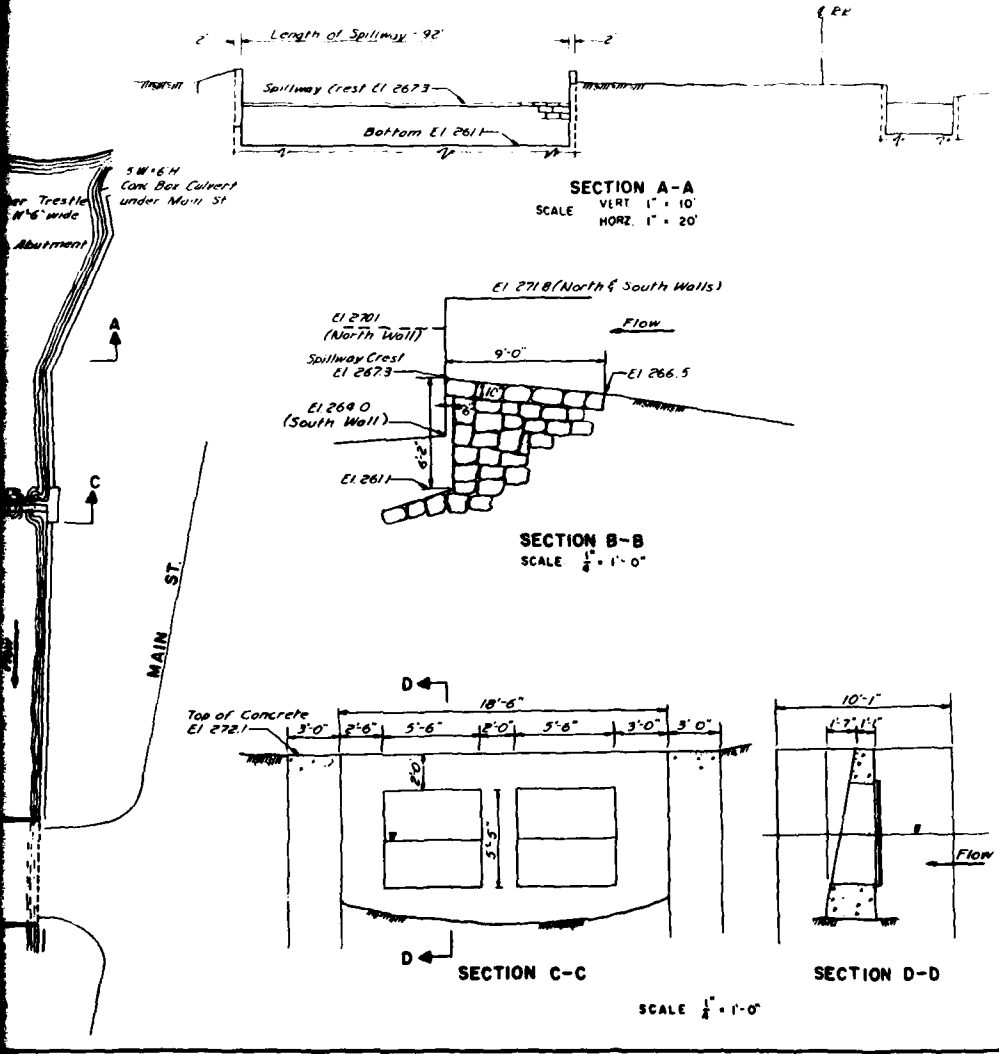
DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE
NONE	NONE	NONE	NONE

INSPECTION BY	INSPECTION DATE DAY MO YR	AUTHORITY FOR INSPECTION
CAMP DRESSER AND MCKEE, INC.	15N[illegible]78	P.L. 92-367

REMARKS


USGS Elevation Mark, El 272.08
Timber Trestle Bridge, 11'6" wide
Conc Abutment
Conc Box Culvert under Main St
Stone Masonry Wall
12" Stone Wall
92'
"The Cooperage" Frame
Granite Wall
Flow
MAIN ST
HARBOR RD.
Top of Concrete El 272.1
PLAN
SCALE: 1" = 20'

TOWNSEND



DAM NO. E-1

NAME	Townsend Harbor Dam
STREAM	Squannacook River
LOCATION	Townsend Harbor, Mass Longitude 71°40'25" Latitude 42°39'09"
DRAINAGE AREA	60.6 Square Miles
TYPE	Stone Masonry Overflow
GENERAL DIMENSIONS	Length 92 ft, Height 6.2 ft
SPILLWAY	Capacity 1290 cfs
OUTLET WORKS	None
POND AREA	48± Acres
POND CAPACITY	33± Million Gallons
BENCH MARK	USGS disc on southeast abutment of R.R. bridge as shown on plan

(2)